SUSTAINABLE DESIGN POLICY AND LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN CERTIFICATION

THESIS

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AFIT/GEM/ENV/08-M14

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Abstract

The 2007 Air Force Sustainable Development and Design Policy mandates the use of Leadership in Energy and Environmental Design (LEED®) criteria for military construction projects. Additionally, the policy authorizes adding two percent of the original building budget to the total building budget in order to fund the resulting sustainable design costs. To determine if the specific sustainable design goals of this policy had statistical support in the population of LEED® certified buildings, the author gathered construction, cost, and utility data on a sample of 160 LEED® certified buildings. Simple correlation and descriptive statistics were used to analyze the resulting database. The correlation analysis suggests that this sample offers no statistically significant correlations between design variables. Furthermore, the descriptive statistics suggest that, although the Air Force policy will certainly achieve some of its goals, the two percent budget increase is likely to be too little to achieve LEED® certification a majority of the time. Without additional design requirements, the analysis also suggests that the policy will not result in buildings that always achieve the utility reduction requirements of the Energy Policy Act of 2005 and Executive Order 13423.

Acknowledgments

I would like to thank my advisor and committee for their inspiration, interest, and efforts. Their guidance allowed me to take an interesting idea and transform it into a graduate-level research project. I would also like to thank my family. Without their support and understanding, this endeavor would have been impossible.

David M. Nyikos

Table of Contents

Page

Page

List of Figures

List of Tables

Page

SUSTAINABLE DESIGN POLICY AND LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN CERTIFICATION

I. Introduction

Background

Over the past 30 years, the United States has enacted laws that specifically mandate increased building efficiency, and in order to satisfy these requirements, federal organizations have been searching for ways to ensure they comply (National Energy Conservation Policy Act of 1978, Energy Policy Act 2005, Executive Order 13423 2005). That search has most recently centered on the concept of sustainable design, which is a philosophy that focuses on the idea that humanity must ensure "…that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987, p 24). A series of design guidelines grew from this philosophy, but one methodology has captured the attention of the federal government. Leadership in Energy and Environmental Design (LEED®) is a construction design tool that aims to incorporate sustainable design; consequently, the Department of Defense (DoD) services, including the United States Army, United States Navy, and United States Air Force (USAF), have created policies that mandate using LEED® (Policy Letter 2006, NAVFACINST 9830.1 2003, Policy Letter 2007).

However, as we enter the seventh year of a global war on terror, the financial ramifications of policy decisions are beginning to come under increased scrutiny. The latest USAF policy authorizes funding sustainable design at two percent of the overall

building cost, but there appears to be limited concrete evidence to justify the policy (Policy Letter 2007). There have been studies compiled by consultants in the civil sector, individual building studies completed by universities, and energy studies accomplished by federal agencies, but there has not been a comprehensive, peer-reviewed, study accomplished (Kats et al. 2003, Stegal 2004, Diamond 2007). This paper attempts to begin to fill that void by analyzing buildings that have achieved LEED® certification.

Research Roadmap

Our goal is to determine whether the goals and criteria specified in the Air Force Sustainable Development and Design Policy (2007), which mandates the use of LEED® design criteria, are supported by the characteristics of the buildings which have achieved LEED® certification. Specifically, I address the following three questions. Does the AF policy have statistical support in the data from the existing LEED®-NC v2.0 and v2.1 certified buildings? Does the population of LEED®-NC v2.0 and v2.1 certified buildings exhibit the same cost and premium trends highlighted in the most frequently cited literature? Are there any trends or correlations between variables that USAF civil engineers can capitalize on during MILCON planning?

I began with a thorough review of the existing policy, law, literature, studies, and information pertaining to sustainable design. Then, I identified a representative sample of LEED® certified buildings and collected data on a series of construction variables. After normalizing the data into similar units, we completed a statistical analysis. Finally, I offer my conclusions based on a comparison of our data to previous efforts and the Air Force Policy.

II. Literature Review

Why the USAF is Concerned about Energy and Water Conservation

Since the National Energy Conservation Policy Act (NECPA) of 1978, many directives have moved the USAF towards energy conservation, but the most recently applicable impacts resulted from the latest executive orders, the Energy Policy Act of 2005, and the newest Air Force Civil Engineer (AFCE) policy letters. In 2001, the AFCE issued a Sustainable Development Policy letter which specified that 20 percent of fiscal year (FY) 2004 military construction projects "should be selected as LEED™ pilot projects," and all projects should be capable of Leadership in Energy and Environmental Design (LEED®) certification by fiscal year (FY) 2009 (Policy Letter 2001, p. 2). This policy introduced energy conservation standards, through the idea of sustainable design guidelines, as design requirements, but the letter's overall suggestive wording left room for interpretation and easy exception.

The NECPA of 1978 directed Congress to provide further guidance in 2005, but in 1992, the Congress passed an Energy Policy Act (EPAct 1992). It required federal agencies to incorporate energy and water conservation features into new buildings as long as the associated payback period for those conservation measures was less than ten years. Additionally, it specified maximum flow rates for plumbing fixtures that are still in use today (EPAct 1992). In 1992, the Office of Management and Budget (OMB) updated *Circular A-94*, which dictated how federal agencies are to conduct benefit cost analyses and calculate payback periods for expenditures.

Keeping with the above requirement to continue to modernize by 2005, Congress created new national energy policy in the Energy Policy Act of 2005 (EPAct 2005). The law mandated, for federal facilities, that the baseline performance year used for comparisons be changed from 1985 to 2003, energy conservation efforts create an overall reduction in energy intensity (MBTUs/ft^2) of 20 percent by FY 2015, and if life cycle cost-effective, buildings were to be designed to 30 percent below the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) energy standard. In January 2007, the President of the United States signed Executive Order (EO) 13423, which was even more restrictive. It required all federal agencies to further reduce their total energy intensity 30 percent below their 2003 energy intensity levels not later than FY 2015 and to reduce their water consumption intensity 20 percent below 2007 levels by FY 2015. Additionally, it requires the Secretary of Defense to report to Congress on how the Department of Defense is meeting that requirement (EO 13423 2007).

Finally, after reviewing the past four FY construction projects, Air Combat Command Civil Engineering determined that the USAF was meeting the intention of the 2001 policy less than 50 percent of the time (Hunt 2007). As a result, the AFCE 2007 Sustainable Development Policy letter reflected the requirement for more stringent guidance to achieve the mandates set forth in EPAct 1992, EPAct 2005, and EO 13423. The wording is much more directive than the 2001 letter. It requires that, by FY 2009, all new USAF military construction will be capable of LEED® certification and a minimum of ten percent will actually achieve it. In order to ensure compliance, those projects that

do not seek LEED® certification must be reviewed by a LEED® accredited professional to ensure the design was capable of achieving certification (Policy Letter 2007).

The LEED® Rating System

In an effort to meet the requirements of the EPAct of 2005 and EO 13423, many government agencies, including the Department of Agriculture, Environmental Protection Agency, General Services Administration, National Aeronautics and Space Administration, United States Army, United States Air Force, and United States Navy have identified LEED® certification as a requirement for new construction (Hartke 2007). As a result, LEED® certification, as evaluated by the United States Green Building Council (USGBC), bears further discussion. The USGBC describes itself as a (About USGBC 2007):

> "…non-profit organization committed to expanding sustainable building practices. USGBC is composed of more than 12,000 organizations from across the building industry that are working to advance structures that are environmentally responsible, profitable, and healthy places to live and work."

While a complete description of each LEED® rating system is available on the USGBC website, the following describes items that pertain specifically to this paper (2007).

In 1999, the USGBC released the LEED Green Building Rating System™ version 1.0. This was a pilot program that sought to create a system that the construction industry could use to achieve sustainable design goals. Using commissioning and evaluation, the USGBC awarded credits for incorporating sustainable design features into the building site, energy efficiency, material use, indoor environmental quality (IEQ), and water. Depending on the number of credits earned, a building could achieve a Bronze, Silver,

Gold, or Platinum level (USGBC 1999). After a couple of years, the pilot program was modified.

In 2001, under contract with the United States Department of Energy (DOE), the USGBC developed and released the LEED™ Rating System version 2.0. Based on feedback from the pilot program, the USGBC changed some of the credits, increased the number of credits, and replaced the Bronze certification level with a Certified level. Water related credits account for 5 of the 69 possible points, and Energy credits account for 17 possible points. Credits associated with water conservation were based on reductions compared to the plumbing fixture requirements of the EPAct of 1992 baseline. Energy efficiency credits were related to annual energy cost reductions in comparison with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 standard; successfully achieving those credits required the submission of whole-building energy simulation to prove the designed levels of efficiency. Of the 17 energy credits, a total of 10 of the 69 available points are related to energy efficiency (USGBC 2001). In 2002, the USGBC began to narrow the categories of buildings it was certifying under the LEED rating system, and for the purposes of this paper, only the rating systems associated with new construction will be discussed.

The USGBC released the LEED™ Green Building Rating System For New Construction & Major Renovations (LEED®-NC) Version 2.1 in 2002. It kept the same standards for comparison and contained only minor changes to the credits associated with certification; the points required to achieve each certified level remained the same: 26-31 credits for Certified, 32-38 credits for Silver, 39-51 credits for Gold, and 52-69 credits for

Platinum (USGBC 2002). In 2005, the USGBC released the most recent changes to its rating system. Other than breaking out new construction categories, this change included removing existing buildings from the new construction category and updating the energy efficiency standard to the latest ASHRAE 90.1 standard (USGBC 2005). Because the rating system had evolved since it was chosen as their standard, the Government Services Agency (GSA) asked the Pacific Northwest National Laboratory (PNNL) to determine if the LEED® rating system was still the best approach for federal agencies. In their 2006 PNNL study, Fowler and Rauch concluded that, although there were other sustainable design tools available, the LEED® rating system was the most favorable to ensure the federal agencies met their legal requirements. Interestingly, sustainable design relies heavily on whole building simulation, and the literature offers insight into the accuracy of the models.

Energy Simulation versus Actual Consumption

A series of studies have been accomplished about the energy performance of buildings incorporating sustainable design. DOE maintains detailed whole building performance information on a series of buildings it calls High Performance Buildings. Additionally, between 2004 and 2005, the National Renewable Energy Laboratory (NREL) completed evaluations on six buildings constructed in the late 1990s that were not designed using LEED® criteria (Deru, Torcellini & Pless 2005; Deru, Torcellini, Sheffer & Lau 2005; Griffith, Deru, Torcellini & Ellis 2005; Pless & Torcellini 2004; Torcellini, Long, Pless & Judkoff 2005; Torcellini, Pless, Griffith & Judkoff 2005). Torcellini et al. (2006) summarized these studies and showed that while the six buildings

showed energy consumption 25 to 70 percent below code requirement, all six buildings were performing significantly below what was predicted in simulations.

The USGBC system relies on energy simulation to certify efficiency, and the accuracy of such simulation has been specifically addressed in two studies that compared actual building utility performance with LEED® submitted simulation data. In the first study, Cathy Turner (2006) evaluated 11 of the 30 LEED® certified buildings in the Cascadia region that had been occupied for at least a year. She determined that one building suffered from serious problems with its heating ventilation and air conditioning (HVAC) systems; if it was removed from the data, the office buildings' actual energy usage was 99 percent of the modeled predicted values. For water intensity, Turner (2006) found that only two of the buildings experienced water usage greater than predicted by simulations. In a similar review, Diamond et al. (2007) evaluated the performance of the first generation of LEED® certified commercial buildings. Their study included 18 buildings which averaged a 27 percent energy savings over the ASHRAE baseline building; the actual energy use mirrored the Turner (2006) study at 99 percent of the modeled values. However, both studies suffered from a small sample size, and Diamond et al. (2007) concluded that more information and study is required.

Studying Costs and Benefits

As mentioned above, the EPAct of 1992 requires the government to determine if the cost of efficient design features will achieve benefits resulting in a payback period of less than ten years. These calculations require the government to determine both the cost

and the benefits of sustainable design. Next, I review the literature that addresses how to properly analyze sustainable design costs and benefits.

Benson Kwong (2004) reviewed benefit cost analysis and how it can apply to sustainability. Specifically, he identified sustainable design costs as those expenses related to initial construction, operations, and maintenance. He also included a list of direct and indirect benefits. Direct benefits result from lower initial costs, reduced utility costs, increased equipment life, and decreased maintenance cost. Kwong (2004) spends a good deal of his paper describing indirect costs, which can be grouped as gains from increased productivity, gains from decreased health losses, and the social and environmental externalities associated with the production of electricity.

Kim Fowler, Amy Solana, and Kathleen Spees (2005) created a building cost and performance data protocol that lists metrics that must be collected, along with metrics that are helpful to be collected, in order to create a comparison to analyze buildings that utilize sustainable design. The required data includes building design specifications, building type, building location, year of completion, gross square footage, type of occupant, number of occupants, total building cost, water consumption, energy consumption, waste production, maintenance costs, turn over details, and absenteeism numbers. This protocol was to be tested by the United States Navy with a set of seven paired buildings, but Fowler (2007) stated that the Navy was unable to provide detailed building information or modeled energy performance for its buildings (2005; personal interview July 23, 2007); therefore, the protocol remains untested.

The Cost of Sustainable Design

While a review of the literature discovered no conclusive studies about the cost of sustainable design, there have been a number of studies that attempted to quantify the costs and benefits. These efforts can be divided into studies about sustainable design and studies about LEED® certified buildings. Allen Lee et al. (2000) reported on three city-owned buildings in Portland that were reviewed to determine what the costs and benefits would have been if these building designs had been altered to achieve LEED® certification. The authors concluded that the building costs would have been increased 0-2 percent to achieve the LEED® Certified level and that the majority of the benefits were associated with increases in worker productivity (Lee et al. 2000).

Greg Kats et al. (2003) created a report for the state of California; it is the most often cited study about costs and benefits associated with sustainable design. This study included the Lee et al. (2000) buildings and 30 other sustainable design buildings in California. Using anecdotal data from personal interviews about the costs associated with achieving energy efficiencies associated with LEED® certification, they made a series of conclusions about the cost premiums for achieving LEED® certification as well as the net present value of the resulting benefits. These values are captured in Figures 1 and 2 below. Interestingly, productivity and health benefits accounted for almost 70 percent of the net present value of Certified or Silver LEED® certification, while utility savings represented only around 12 percent. About 82 percent of the net present value of Gold or Platinum LEED® certification was the result of health, with productivity benefits, and energy savings accounting for only around 9 percent of the net present

Figure ES-1. Financial Benefits of Green Buildings
Summary of Findings (per ft^2)

Category	20-year NPV
Energy Value	$5.79
Emissions Value	$1.18
Water Value	$0.51
Waste Value (construction only) - 1 year	$0.03
Commissioning O&M Value	$8.47
Productivity and Health Value (Certified and Silver)	$36.89
Productivity and Health Value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-year NPV (Certified and Silver)	**$48.87**
Total 20-year NPV (Gold and Platinum)	**$67.31**

Source: Capital E Analysis

Figure 1. Summary of financial benefits of green buildings (Kats et al. 2003, p. ix).

Figure III-1. Level of Green Standard and Average Green Cost Premium

Level of Green Standard	Average Green Cost Premium
Level 1 – Certified	0.66%
Level 2 – Silver	2.11%
Level 3 – Gold	1.82%
Level 4 – Platinum	6.50%
Average of 33 Buildings	1.84%

Source: USGBC, Capital E Analysis

Figure 2. Cost premium for LEED® certification by level (Kats et al. 2003, p. 15).

value. The authors note the limited sample size, but their data suggests an increasing trend in cost premiums associated with higher LEED® certification. Additionally, the

authors used California emissions data to estimate that roughly two percent of the present value is due to environmental externalities saved by a reduction in energy consumption (Kats et al. 2003). However, while all the buildings included in this study were designed to LEED® standards or registered for certification, only five of the buildings actually achieved LEED® certification (Kats et al. 2003; Certified Project List 2007). The same group conducted a similar study about sustainable design and schools, and their results were much the same. However, worker productivity was replaced with increased student learning resulting from better daylighting (Kats et al. 2005).

In 2003, the DOE released a report describing why sustainable design in construction was a good business decision. It included a hypothetical 20,000 square foot building constructed in Maryland and compared the costs of constructing the structure to the minimum standards required by code with the costs of incorporating a series of sustainable design features. Interestingly, the authors' conclusions related to utility and emissions savings were similar to those offered by Kats et al. (2003). In this case, the utility savings from using energy efficient designs accounts for about 12 percent and emissions account for about 4 percent of the total savings. However, they concluded that the majority of the benefits, almost 75 percent, would come from incorporating design strategies that minimized costs associated with personnel turnover and the work area layout (DOE 2003).

Steven Winters Associates (SWA), Incorporated, under contract from the GSA, conducted a cost study about achieving LEED® certification for a new construction building and a major renovation (2004). One of the study's intents was to determine if

the 2.5 percent of facility budget authorized for buildings seeking LEED® certification was an effective policy. After calculating low and high cost estimations for Certified, Silver, and Gold certification, the authors concluded that the GSA could expect increasing cost premiums for higher LEED certification similar to the results of Kats et al. (2003). In their study, the premiums varied from a 0.4 percent savings for the low Certified estimate to an 8.1 percent premium for the high Gold estimate (SWA 2004).

Nathan Stegal (2004) and Christopher Weber (2004) conducted simultaneous studies on the New House Residence Hall at Carnegie Mellon University. This building sought and achieved LEED® Silver certification; Stegal analyzed the costs while Weber studied the benefits. Stegal (2004) concluded that the cost premium for LEED was between 1 and 2.8 percent, and even though the building was a little more than 20 percent more efficient than a building built to code, the energy efficiency was between 6 and 12 percent worse than less than similar Carnegie Mellon buildings that did not seek LEED® certification but incorporated energy recovery systems. He concluded the added energy consumption was related to the LEED® requirement for extra ventilation (Stegal 2004). Weber (2004) took Stegal's (2004) costs and conducted a cost-benefit analysis for the same building; he concluded that the net present value to the university to incorporate sustainable design in New House was likely in the millions of dollars. Weber's (2004) study is unique in that he utilized a contingent valuation (CV) survey to account for non-market values associated with green design features.

Lisa Fay Matthiessen and Peter Morris (2004), working for Davis Langdon, completed a study of the LEED® building rating system by doing a credit-by-credit cost

analysis and comparison of LEED® and non-LEED® designed buildings. The study analyzed 138 buildings, which included 45 LEED® seeking structures. The authors determined the cost premium of seeking LEED® certification and organized the premiums by location. Their cost premiums to achieve LEED® Silver, Gold, and Platinum were similar to those found by Kats et al. (2003) and varied from 1 to 10.3 percent as certification level increased (Matthiessen & Morris 2004). As seen in Figure 3, the authors graphed the cost per square foot of all 138 buildings to show the concept that LEED® (not blue) and non-LEED® (blue) designed buildings costs vary significantly, and more specifically, the cost variation of LEED® seeking buildings is within the cost variation of non-LEED® seeking buildings. Three years later, the same authors repeated their analysis, and reviewed a total of 221 buildings, which included 83 that were designed to achieve LEED® certification. The results were almost exactly the same as the previous study (Matthiessen & Morris 2007).

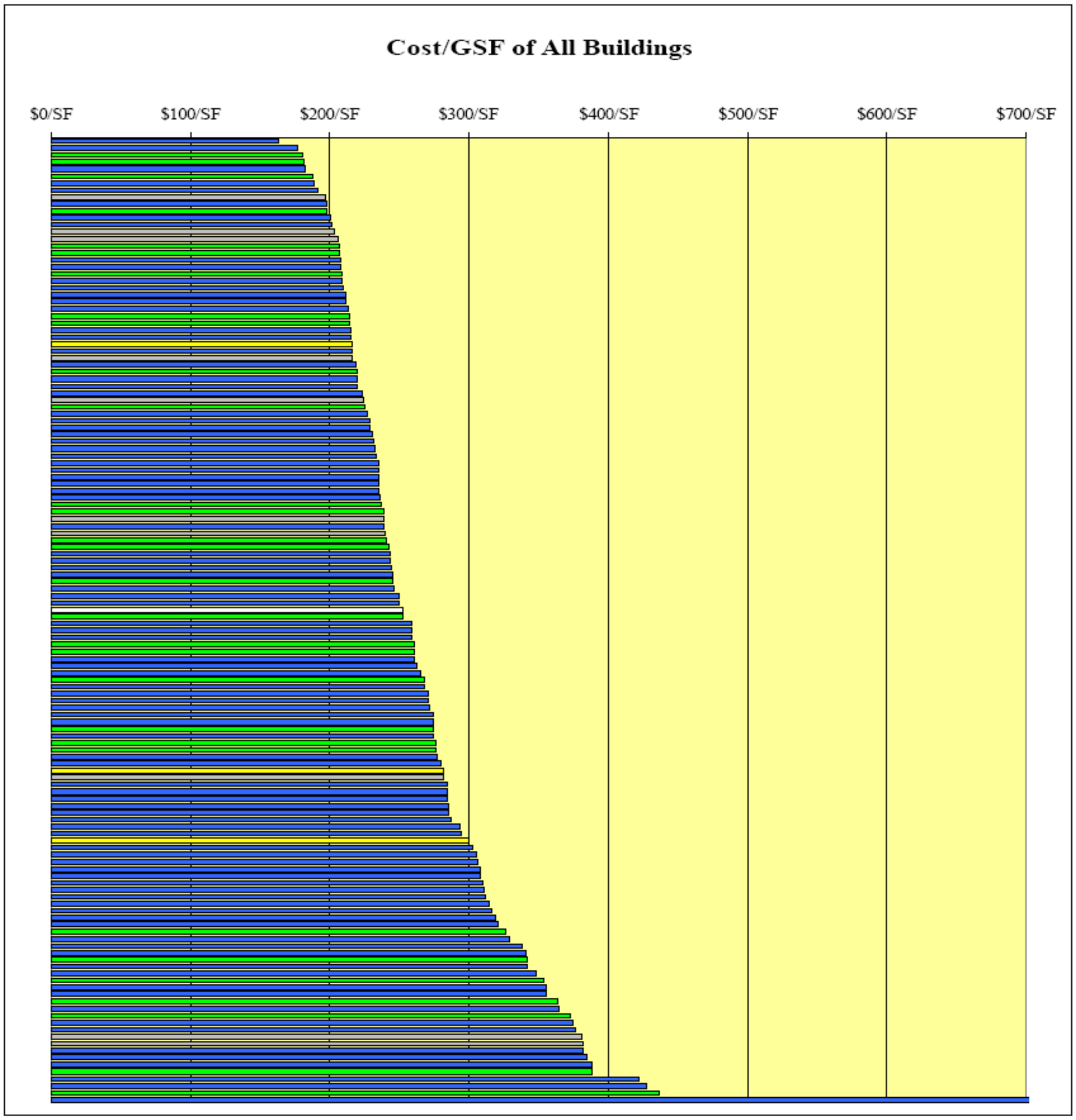


Figure 3. Building cost per square foot (Matthiessen and Morris 2004, p. 18)

Productivity and Environmental Externalities

Many of the above studies cited large benefits resulting from some type of increase in productivity, and a number included values for environmental externalities

associated with energy production (e.g. Lee et al. 2000, Kats et al. 2003, Weber 2004). Since these benefits were responsible for such a large portion of the cited positive values related to sustainable design, the literature was reviewed to determine if these effects should be included in this study.

An increase in worker productivity as a result of decreased sickness was associated with improved indoor environmental quality (IEQ) by William Fisk (2000, 2002) and Donald Milton, Mark Glencross, and Michael Walters (2002). Fisk's work focused on how better workplace air quality tends to decrease occurrences of respiratory problems, asthma, allergies, and sick building syndrome. In both studies, Fisk (2000, 2002) based his benefit values on the medical literature available and concluded that one of the side effects of increased energy efficiency is improved IEQ (2000, 2002). Milton et al. (2002) studied how sick leave was associated with ventilation. Their work was based on a single company with multiple work areas and varying levels of ventilation. The authors concluded that the frequency of a worker requiring sick leave was strongly associated with the amount of outdoor air ventilation in that employee's work area (Milton et al. 2002). While these studies connect worker productivity and improved IEQ, they do not suggest that the effects associated with LEED® certification are any greater than those associated with new construction built to current code. The 2005 Building Design Council annual report on the green building movement appears to suggest the exact same thing.

> The biggest disappointment, though, is that we still have no scientific study by a major federal research agency (such as the National Research Council) proving definitively that green buildings, whether LEED or otherwise, are in fact "healthier" for occupants, or that they do indeed make workers (in offices or

> factories) and children (in schools) more productive. That's a huge shortcoming. (Cassidy, Barista, & Yoders 2005, p. 61)

Including the social and environmental impacts of energy generation was also popular in the above studies. In the literature, such environmental externalities are commonly captured using contingent valuation (CV) and the cost of emissions. CV studies, like the one Weber (2004) used, attempt to measure the value of items that have no market by which one could base the valuation (Boyle 2003). For example, air pollution has been linked to both poor respiratory health and to poor visibility. Loehman (1984, 1994) studied how much value residents of the San Francisco Bay area placed on air quality by determining their willingness to pay (WTP) for better visibility and fewer unhealthy air quality days. Similarly, Farber and Rambaldi (1993) estimated the WTP of outdoor exercisers in New Orleans. When applied to a local or national population, such WTP estimations can help determine a value for the externalities associated with electricity generation (or savings). However, Rozen (2004) suggests that due to differences in personal preferences such WTP values may not be transferable across different populations. Although her research focused on the variation between preferences in Germany and France, similar distinctions could be envisioned for the difference between California and Kansas.

On the other hand, by using the cost of emissions for electricity generation, a value for each kWh saved can be calculated from the amount of emissions prevented (Kats et al. 2003, DOE 2003). Kats et al. (2003) reported on projects in California, and the authors used California emissions which, without carbon dioxide emissions, averaged about $0.0249 per kWh. Lee et al. (2001) dedicated their research to the environmental

externalities related to the production of electricity in South Carolina and placed the average value for these externalities at $0.00125 per kWh. This estimation is similar to the four-study range produced in Krupnick's (1996) review of the social costs of electricity production where he determined those costs ranged between $0.001 - $0.019 per kWh.

Summary

This review defined the laws and directives surrounding the USAF sustainable design policy. Additionally, it detailed the background of LEED® design criteria and the costs and benefits associated with sustainable design. Armed with a better understanding of the wide array of variables associated with the research questions, I began the search to collect data from a sample of LEED® certified buildings.

III. Methodology

Population of Interest

In order to evaluate the Air Force Sustainable Development and Design Policy (2007), a population of buildings must be identified. Since this policy focuses on new construction and mandates LEED® certification, this study will focus on LEED® for new construction (LEED®-NC) certified buildings. As previously mentioned, LEED®-NC certification criteria has gone through four iterations. However, it is noteworthy that 714 of the 739 certified buildings listed on USGBC's website as of August 31, 2007, were certified under Version 2.0 (LEED®-NC v2.0) or Version 2.1 (LEED®-NC v2.1). Additionally, Version 1.0 (LEED®-NC v1.0) and Version 2.2 (LEED®-NC v2.2) both use a substantially different edition of the ASHRAE 90.1. LEED®-NC v2.0 and v2.1 use ASHRAE 90.1-1999, but v1.0 uses ASHRAE 90.1-1989 which requires significantly less energy efficiency than the 1999 standard (USGBC 1999, 2001, 2002). For example, the 1989 standard for maximum lighting power density was 1.8 watts per square foot, and the 1999 standard was 1.3 watts per square foot (FEMP 2007). LEED®-NC v2.2 uses ASHRAE 90.1-2004 which not only requires more energy efficiency (i.e. maximum lighting power density of 1.0 watts per square foot), but it also mandates that, for the first time, plug loads be included in the energy calculations (USGBC 2005, Black, Lewis, & Thornton 2006, FEMP 2007). In an effort to capture comparable energy data and the greatest number of buildings, this study incorporates only buildings in the United States that were certified under the LEED®-NC v2.0 or v2.1 rating systems.

Sample Data

While it would be preferable to obtain data on every building in the population of interest, USGBC allows owners to keep building utility and construction data confidential (Certified Project List 2007). As a result, the next best option is to draw a representative sample and create a database containing construction variables of interest. The population of buildings was examined to identify the number of certified buildings in each level of LEED® certification and in each state. To ensure that the sample contained data that could be used to evaluate the Air Force Sustainable Development and Design Policy (2007), a series of items were deemed necessary for a building to be selected.

Therefore, the year of completion, cost, square footage, and LEED® certification scorecard were required for a building to be included in the study. The completion date allows the costs to be normalized into a single year. Cost information was available in many forms; the total construction cost, including soft costs and fees, was selected. This prevented including furniture and equipment to the maximum extent possible (the only known exception was building 74, see Appendix A). Total cost and square footage were used to calculate a cost per square foot unless only a cost per square foot was available. Square footage was also used to normalize water, energy, and green cost information into units per square foot. Since the USGBC includes gross square footage (GSF) in their online registered project details, GSF was chosen for the database (Registered Project List 2007). However, if the project area could be verified as having been changed, a self-reported GSF was used instead. The LEED® scorecard was required to verify, and sometimes to provide, the percent water reduction and percent energy reduction.

While not required for a building to be included in the current study, additional variables were gathered to better evaluate the Air Force Sustainable Development and Design Policy (2007). Therefore, any information pertaining to water or energy consumption or savings, the owner, and the location was also recorded. Furthermore, all cited renewable energy facts, utility cost savings, green construction costs, and sustainable design tax benefits were captured. If case studies described utility consumption or savings changes resulting from post-occupancy monitoring, the original LEED® certification data was used. This rational is based on the fact that these changes were the result of further financial investment that was not captured in the costs gathered.

With the sample requirements and variables of interest determined, a sample of convenience was drawn. A random sample would have been more desirable, but the limited nature of the construction and utility data eliminated that possibility. Previous studies have not made their data available for further study, but three organizations maintain large databases of LEED® certified building case studies. The USGBC database contained 81 projects (Certified Project List 2007); the United States Department of Energy, Energy Efficiency and Renewable Energy (EERE) database listed 40 buildings (EERE 2007); the BuildingGreen.com database held 87 LEED® case studies (Projects 2007). Although some of the case studies lacked one or more of the required variables there was sufficient overlap to determine any missing information. While these three databases accounted for a majority of the buildings eventually gathered, there were still many other LEED® certified buildings with construction and utility data available elsewhere.

After the above three sources were incorporated into the database, the resulting sample was compared to the population by both state and certification level (but not both together) to determine which states needed to be further researched and which certification levels needed more cases. To fill in the gaps, a substantial number of new buildings were identified by using the USGBC Certified Project List (2007) and searching the World Wide Web. Construction and utility data were gathered from regional green building, local government, architectural firm, engineering company, and university building program website case studies. The required variables were often completed by comparing multiple sites along with using local newspaper and trade journal articles. Each building that was entered into the database had at least one online data source, and these are documented in Appendix B. The final database, with 160 LEED®-NC v2.0 or v2.1 certified buildings, is the largest known collection of LEED® certified building data including cost and utility data, and as a sample, it is relatively representative of the population by certification and by location (see Figures 4 and 5 below).

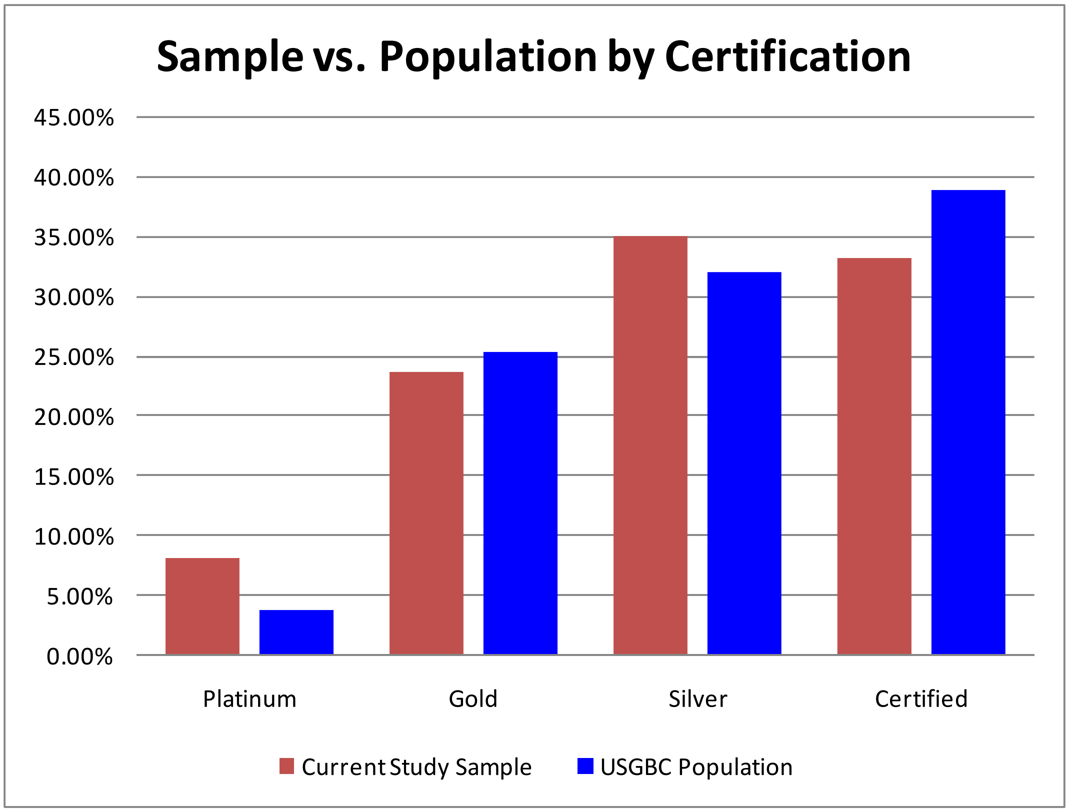


Figure 4. Comparison, by certification level, of the Study Sample and the USGBC Population of LEED®-NC v2.0 and v2.1certified buildings.

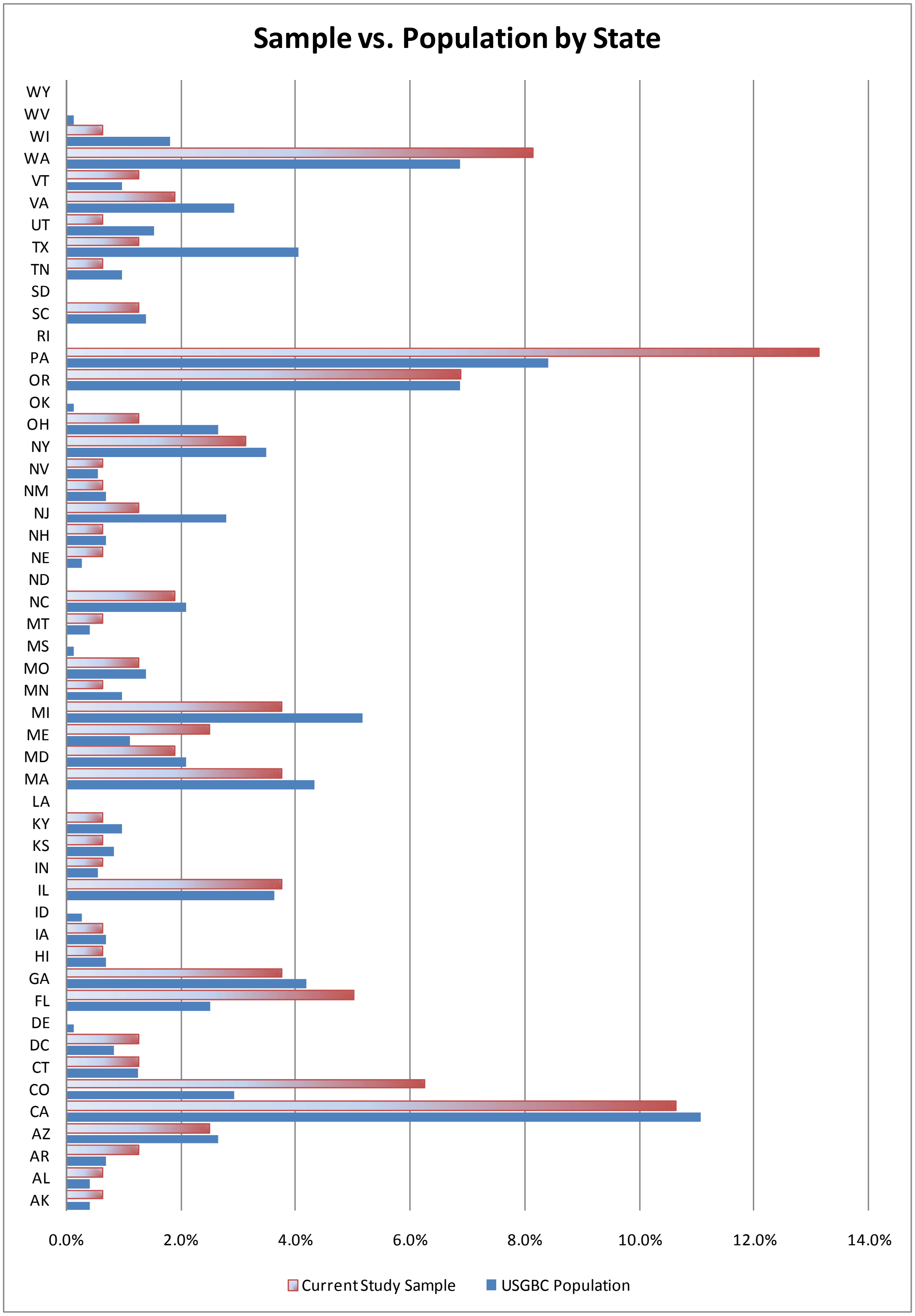
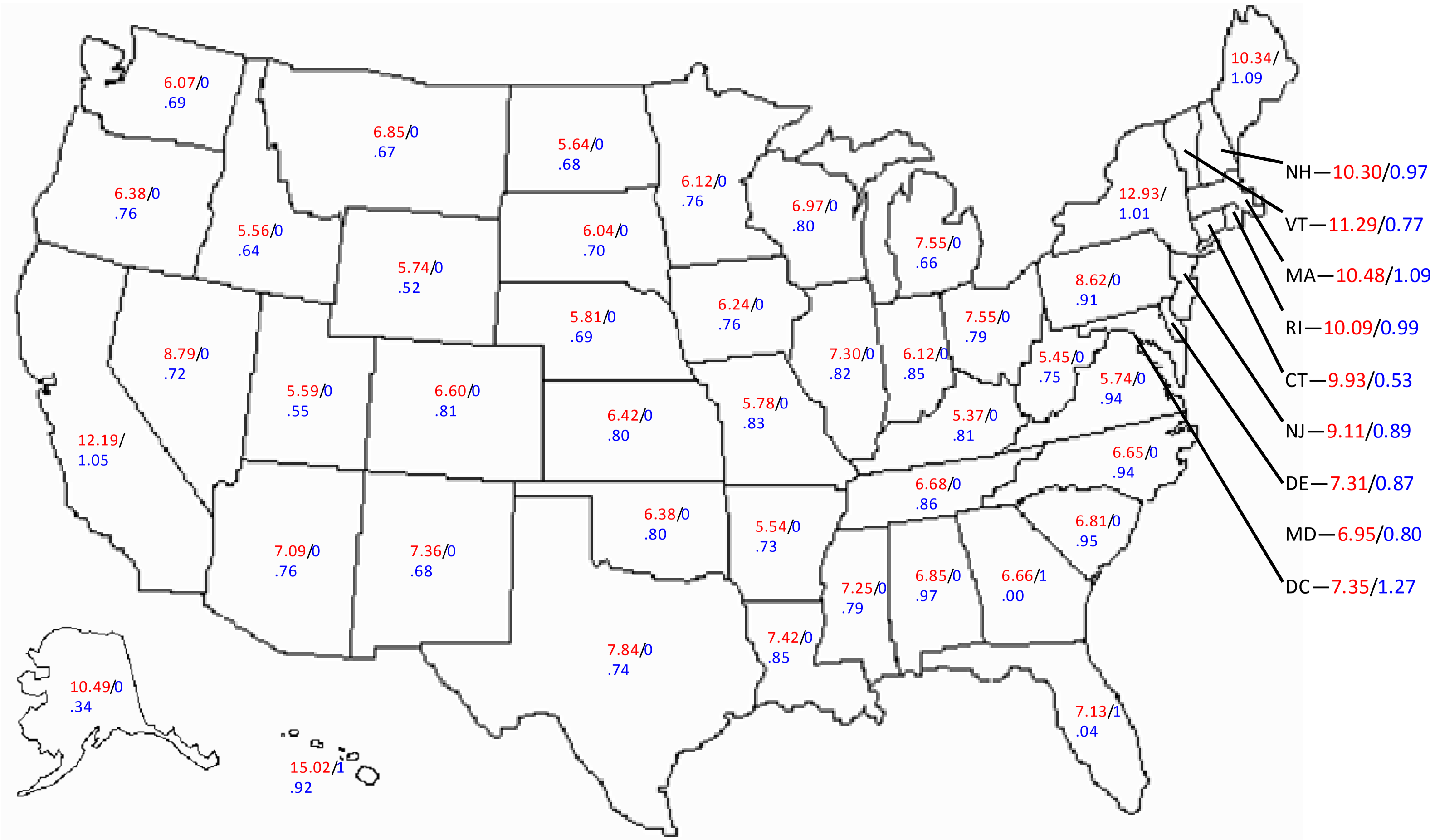


Figure 5. Comparison, by location, of the Study Sample and the USGBC Population of LEED®-NC v2.0 and v2.1certified buildings

Additional Information and Categorization

Since building construction intuitively varies in relation to the local cost of living and climate, it was necessary to capture those variations in this study. In the database, each project was associated with a building type, located into a region, and linked to a state commercial cost of electricity and natural gas (see Appendix C and figure 6). The EERE, USGBC, and BuildingGreen.com case studies shared the same building classification system, and since those buildings made up a majority of the included cases, those building types were selected as a standard. For case studies which did not cite a building type, the associated facility descriptions were used to place the building in one of the aforementioned categories. If multiple building types were cited, the type that accounted for the majority of the floor space was chosen.

To capture regional differences, three regional designation systems were compared. The National Oceanic and Atmospheric Administration (NOAA) regions and major United States Census regions were very similar. However, the Regional Reliability Councils (RRC), which are divided into eight regions based on the national power grid system, offered another option related to regional energy costs (Forecast Offices 2007, RRC 2007). Grouping the Energy Information Administration (EIA) 2003 state average commercial energy prices by the RRC divisions did not reveal any notable trends in the costs of energy (see Appendix C) (EIA 2005, 2006). NOAA puts Alaska and Hawaii into their own regions, but the Census regions includes them as shown in Figure 7. After reviewing the options, the Census region was selected, and each project was assigned a regional identification based on the state in which it was constructed.



Source: Energy Information Administration. 2006. "State Electricity Profiles 2003." U.S. Department of Energy. April.; Energy Information Administration. 2005. "Natural Gas Monthly." U.S. Department of Energy. November. Map courtesy of www.50states.com

Figure 6 Commercial Cost of Electricity (cents/kWh) and Natural Gas (cents/kBtu) by State, 2003

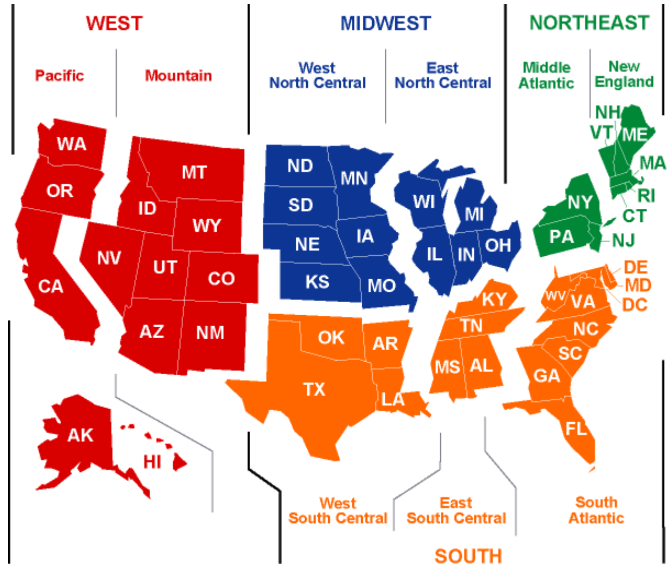


Figure 7. Census Regions courtesy of EIA (http://www.eia.doe.gov/emeu/reps/maps/us_census.html)

Productivity and externalities benefits were not included or calculated in this study because they do not impact the USAF bottom line of either ownership costs or construction premiums. Due to the nature of the mission and the fact that end-strength manning is dictated by Congress, there is very little direct connection between manning and current worker productivity. Finally, using the Lee (2001) and Kats et al. (2003) emission-only externality values combined with the DOE (2003) annual savings average building size, the estimated average per square foot annual emissions-only externality value is about $0.03 per square foot. Based on the anticipated accuracy of the secondary data gathered and manipulated for this study, the value of externalities will not be significant to the research questions as posed in Chapter I.

Utility savings was chosen as a proxy for the USAF policy goal of reduced ownership costs. To determine the value of utility savings, it was necessary to

approximate the commercial cost of electricity, natural gas, and water. The EIA is the division of DOE that tracks energy prices, and they report prices for residential, commercial, industrial, and other sectors (About Us 2007). This study applies to the commercial sector as defined by EIA below (Glossary 2007, Commercial Sector):

> Commercial sector: An energy-consuming sector that consists of service-providing facilities and equipment of: businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities.

Using the EIA values and approximating total fuel costs with the commercial cost of natural gas, each building was assigned a commercial electricity cost and a natural gas cost for the year 2003. The cost of water was much more difficult to identify due to a large variation of prices even at the city level, but the NUS Consulting Group, a division of National Utility Service, Incorporated, produced a 2005 report on water cost and quality which gave an average price per cubic meter (NUS Consulting Group 2005). This value was converted to gallons by dividing by 264.712 gallons per cubic meter, and then it was converted to 2003 constant year dollars as described further below (Volume 2007).

Data Modification

Due to the variety of sources from which the data were gathered, it was necessary to normalize all of the various numbers into consistent units. Water data were converted to gallons and gallons per square foot. Electricity data were converted to kilowatt hours (kWh) and kWh per square foot. Fuel data were converted to thousands and millions of

British Thermal Units (kBTU and MBTU, respectively) and BTUs per square foot. All energy conversions were made using the factors listed in Table 1 below.

Table 1. Energy Conversion (Industrial Assessment Center 2007).

1 kWh	=	3.6 MJ
1 kWh	=	3.413 kBtu
1 Therm	=	100 kBtu
100 CF (natural gas)	=	100 kBtu

Energy consumption figures also needed to be standardized. Since LEED®-NC v2.0 and v2.1 grade energy consumption based on ASHRAE 90.1-1999, plug loads should be removed from total energy consumption (USGBC 2001, USGBC 2002). Many of the case studies broke out plug loads in their description of energy use; for these cases, the plug loads were removed. Other case studies did not list a total energy consumption figure, but they listed electricity, fuel, and renewable usage energy totals. In these cases, building energy consumption was calculated by adding electricity purchased, fuel purchased, and renewable energy generated. However, these calculations can be incomplete since the energy generated from solar heat and geothermal systems were not always given. Additionally, this error was transferred to the savings data.

Energy savings were detailed in many different formats, and often the cited energy savings were substantially different than the associated LEED® credit for energy reduction. In instances where energy savings were cited without earning LEED® credit for any energy reduction, zero energy reduction was entered into the current study's database for that building (reference Appendix A). However, if LEED® certification was earned for energy reductions, energy savings were cited and based on comparison to ASHRAE 90.1-1999, and those savings were between LEED® credit levels, then the cited

savings were used. For example, if a building was given LEED® credit for a 25 percent energy reduction and the case study cited a 28 percent energy reduction compared to ASHRAE 90.1-1999, 28 percent was entered into the current study's database. On the other hand, if LEED® certification was earned for energy reductions and the cited energy savings listed were greater than the next LEED® credit, the LEED® credit earned was used. For example, if a building was given LEED® credit for a 25 percent energy reduction and the case study cited a 35 percent energy reduction, 25 percent was entered into the database. Additionally, if LEED® certification was earned and no, or lower reductions were cited, the energy reduction corresponding to the LEED® credit earned was entered in the database. This same logic was applied to water reduction. Finally, LEED®-NC v2.0 and 2.1 award energy credits for different energy reductions based on whether the construction was deemed "new" or "existing" (USGBC 2001, USGBC 2002). When a cased study failed to describe whether "new" or "existing" building criteria were used, "existing" criteria were only used if the majority of construction could be inferred as a renovation. Otherwise, the "new" criteria were applied. A "Construction Type" column in the database was created to annotate this important difference.

Some case studies listed the electricity and fuel savings, but the other cases required those values to be calculated based on the percentage of energy reduction. LEED®-NC v2.0 and v2.1 award credits for reductions in energy cost compared with a baseline building meeting the ASHRAE 90.1-1999 standard. However, in order to determine the electricity and fuel savings, a noteworthy assumption was required. The percent energy reduction was applied to the electricity consumption and the fuel

consumption to determine what the usage would have been without the reduction, and the actual or modeled usage was then subtracted from that total to determine the kWhs and kBtus saved. This creates an over or under estimation depending on what types of energy savings the building designers incorporated, how the total energy is distributed between electricity and fuel, and the difference in electricity and fuel prices. For example, if a project achieved a 25 percent energy reduction from saving only fuel energy, the database would over report dollar savings because no electricity was actually saved. This could then be compounded depending on the price of electricity and the price of fuel. However, when considering the 160 buildings as a whole, it was assumed that the effect of these estimated savings errors were negligible.

Renewable energy generation was also presented in various formats that required consolidation and standardization. The units for on-site renewable energy generation were converted into kBtu with the conversion factors shown in Table 1. However, photovoltaic (PV) arrays presented an interesting problem. Sometimes the annual electricity production was listed, and it was entered as cited in the case study. Other times the PV array was cited with a kW rating but no annual production, and it was necessary to convert that into an expected annual kWh production. This was accomplished by using available solar calculator algorithms that combine the rated power and local climate data for the city where the building was constructed. Two online calculators were employed for these conversions. For buildings in Oregon, the Oregon Solar Electricity Industries Associates' Solar Calculator was used (Oregon Solar Calculator 2007). The remaining required conversions were made with the National

Renewable Energy Laboratory's "The PV Watt Photovoltaic Solar System Performance Calculator" (NREL Solar Calculator 2007).

As previously mentioned, utility savings were used as a proxy for reduced operating costs. The value of those savings originated from either the case study or data calculated by multiplying each utility's savings with its corresponding rate and summing the resulting water, electricity and fuel savings. Reference the main database columns in Appendix A. The "Utility Savings" column was populated based on a series of criteria. In cases where utility savings were cited in the case study and water, electricity, and fuel utility information was available to calculate the savings, the calculated savings was entered, and the "Utility Savings Based On" column is marked "Calc EFW." However, if the case study cited a utility savings but did not provide electricity and fuel data to calculate the utility savings, then the cited savings was entered, and the "Utility Savings Based On" column is marked "Cited." If the case study did not cite a value for utility savings but did provide some water, electricity, fuel, or renewable energy generation data, then a partial utility savings was calculated and entered into the database. In this case, the "Utility Savings Based On" column is marked in the corresponding combination of "Calc" and "W," "E," "F," and/or "R."

Before calculating a green premium, it must be defined. Previous efforts have defined the premium for using sustainable design as a cost premium (e.g. Kats et al. 2003, SWA 2004). However, they calculated it differently, and their methods did not capture the actual costs of green or sustainable features. For example, Kats et al. (2003) defined the cost premium as the percentage of the total construction cost that exceeded

the average total cost for that type of building in that specific location. Matthiessen and Morris (2004) cited the percentage of the total cost that exceeded a traditional none sustainable design building budget. In the current study, the green premium was defined as the cost to incorporate green design and sustainable construction features, and represented it as a percentage of the total construction cost as shown by the equation below.

Green Premium = (Incremental Cost) / (Total Cost - Incremental Cost)

Incremental costs included: LEED® registration and certification fees; extra commissioning fees; solar heating systems, geothermal systems, PV systems and their support systems above code requirements (wiring, batteries, busses, etc.). As a result of using this definition, projects which cited no cost premium for the reason that the total cost fell within industry standards are not listed in this study as having zero green premium (e.g., buildings 33, 67, 88, and 144 in Appendix A). When sustainable design costs could not be separated from other building upgrades, the case study cited premium was not included (e.g., building 105, in Appendix A, included unique humidification equipment). However, if the cost premium cited was based on the added cost for sustainable design, it was used as the green premium. If a premium range was cited, the mid-point of that range was used. More often than not, the green premiums included were incomplete because not all sustainable design system costs were broken out (e.g. building 106, in Appendix A, listed green costs without the cost of the PV system because it was donated). The overall result is that the green premium listed in the database is more than likely a low estimate of the costs associated with sustainable design

for that building. Interestingly, if the green costs were not listed, they often could be estimated using cited payback periods and tax benefits.

When a payback sum was listed as representing the incorporation of green technologies and design features, that figure was used to estimate the green incidental cost required to determine the green premium. The Office of Management and Budget (OMB) *Circular A-94* (1992) directs using the United States Treasury Rate as the discount rate when evaluating the costs and savings of energy efficient buildings; a historical record of these rates is shown in Appendix C of *Circular A-94* (2007). Most of the payback periods of the buildings in the current study were shorter than ten years, and the corresponding Treasury Rate was about five percent (OMB 2007). With the given payback period and annual savings, the present value of annuity equation below was used to calculate the present value using an interest rate of five percent.

$$PV = (A / r)*[1 - (1 + r)^{(-t)}]$$

Where:

PV = the present value
A = the annual savings
r = the interest rate
t = the payback period in years

This calculated value became the incidental green cost for buildings 98 and 140 (Eschenbach 2003). If the project was awarded tax benefits as a result of using energy efficient designs, those benefits were used to determine a cost premium (e.g. buildings 112 and 114). For example, the Oregon Business Energy Tax Credit states, “The tax credit is 35 percent of the incremental (or addition) costs of making the project exceed energy code or standard industry practice” (Business Energy Tax Credit 2007). For the

buildings that cited these tax credits, the dollar amount given was used with the above tax credit percent to calculate the original incremental costs using the equation below.

Incremental Cost = (Cited Tax Credit Value) / (Tax Credit Percent)

Finally, to effectively compare different costs, all amounts needed to be converted to constant dollar year values. A common method of converting the costs from different years into a constant dollar amount involves using historical values of the consumer price index (CPI). The United States Department of Labor's Bureau of Labor Statistics calculates, tracks, and records the CPI for the United States. The years 1982 to 1984 were used to create a baseline value of 100, and the price index varies from that value based on the buying power of the American dollar (Bureau of Labor Statistics 2007). However, to use the CPI to normalize costs into a single year, a constant year must be chosen.

The majority of the buildings in the database were completed in 2004 and 2003, however, between those two years, the electricity and natural gas values were only available for 2003. As a result, the constant dollar year 2003 was selected. Next, a ratio between the CPI for the original cost and the CPI for the constant dollar year is calculated for each year in the data. Then the ratio corresponding to the original price year is multiplied by each original price, and the result is the constant year value for all dollar values. This conversion is shown mathematically in the equation below, and it was applied to all dollar values in the database (CPI Tutorial 2007).

$$CDYV = OV * (CDY\ CPI / OPDYCPI)$$

Where:

CDYV is the Constant Dollar Year Value
OV is the Original Value
CDY CPI is the Constant Dollar Year Consumer Price Index
OPDY CPI is the Original Price Dollar Year Consumer Price Index

The final database contains over 60 columns of information detailing numeric and non-numeric variables for each building; the complete database is available in Appendix A. While all of these variables were necessary for data organization, validation, or manipulation, only a portion of them are required to answer the research questions posed in Chapter I. These variables of interest are described with their units in Table 2. In addition to these quantitative variables, a series of qualitative variables were coded as dummy variables to allow them to be used in correlation analysis. The dummy variables are grouped into five categories: region, owner, construction type, building type, and renewable energy generated. For each building, all dummy variables are coded with a one or a zero. The region category required four dummy variables to account for the West, Midwest, South, and Northeast Census regions. Since the owner, construction type, building type, and renewable energy generated categories are binary, they needed only two dummy variables each to explain the two options. The owner category was split into government and commercial, construction type was divided into new or renovation, and renewable energy generated was either yes or no. Since commercial offices accounted for over 25 percent of the sample, the building type category was coded with the options commercial office and other. With the data normalized and coded properly, it was ready to be analyzed.

Table 2. List, description, and units of key variables.

Variable Name	Description	Units
Floor Area	Gross square footage of the building	Square Feet
Water Reduction	Water reduction beyond Energy Policy Act of 1992 requirements (excluding irrigation)	Percent
Water Intensity	Annual water used per square foot (excluding irrigation)	Gallons / Square Foot
Water Intensity Savings	Annual water savings per square foot (excluding irrigation)	Gallons / Square Foot
Water Rate	Average Water Rate for the United States for 2005	2003 Dollars / Gallon
Value of Water Intensity Savings	Dollar value of annual water intensity savings (exlcuding irrigation)	2003 Dollars / Square Foot
Energy Reduction	Energy cost reduction in excess of ASHRAE 90.1-1999 requirements	Percent
Electricity Intensity	Annual electricity used per square foot	kWh / Square Foot
Electricity Intensity Savings	Annual electricity savings per square foot	kWh / Square Foot
Commercial Electricity Rate	Comercial cost of electricity by state	2003 Dollars / kWh
Value of Electricity Intensity Savings	Dollar value of electricity intensity savings	2003 Dollars / Square Foot
Fuel Intensity	Annual fuel used per square foot	kBtu / Square Foot
Fuel Intensity Savings	Annual fuel savings per square foot	kBtu / Square Foot
Commercial Natural Gas Rate	Comercial cost of natural gas by state	2003 Dollars / kBtu
Value of Fuel Savings	Dollar value of fuel savings	2003 Dollars
Value of Fuel Intensity Savings	Dollar value of fuel intensity savings	2003 Dollars / Square Foot
Total Energy Intensity	Annual total energy use per square foot	kBtu / Square Foot
Renewable Energy Onsite	Yes or No description of building on-site renewable energy generation	Text
Renewable Energy Intensity	Renewable energy generated per square foot	kBtu / Square Foot
Total Construction Cost Per Square Foot	Total cost of building excluding land, furniture, and equipment per square foot	2003 Dollars / Square Foot
Utility Savings Based On	Case study cited or calculated utility savings using water, electricity, and fuel savings	Text
Utility Savings	Dollar value of utility savings	2003 Dollars
Utility Savings Per Square Foot	Dollar value of utility savings per square foot	2003 Dollars / Square Foot
Green Premium	Percent of total construction costs related to green design and sustainble features	Percent
LEED Points Earned	LEED Points Earned	None

IV. Analysis and Results

Introduction

This chapter details how the set of data was analyzed. After briefly describing the tools used, the analysis begins, and the discussion flows by addressing each research question in order. First, the question is operationalized in terms of the variables gathered, and then the results of the analysis are described.

Analytical Tools

Although the building data was compiled, modified, and organized in Microsoft® Office Excel®, it was imported into SPSS® 15.0 for Windows to complete statistical analyses, including determining the mean, median, and standard deviation for each of the quantitative variables. After incorporating the dummy variable representations of the qualitative variables, SPSS® was used to create a correlation matrix for the entire data set. Upon first glance, this data set appears to lend itself to regression analysis, but after further review such technique shows little promise. The database is riddled with missing data, and it is difficult to control for the multitude of construction variable variation between buildings. As an example, one office building may require using limited numbers of windows and mandate a site-specific orientation, but another could be allowed to utilize daylight from large groups of windows by being optimally oriented on the selected site. Additionally, the literature review revealed no equations pertaining to energy reduction, water conservation, operating costs, or cost premiums that combined the gathered construction variables. Worse still, when more than five variables are

studied together, the listwise sample size decreases tremendously. Finally, very few variables showed significant correlation. For these reasons, regression analysis was not explored further. However, the combination of the original raw data, descriptive statistics, and correlation matrix provided the necessary means to investigate the research questions.

Air Force Policy

The first research question was addressed by breaking the Air Force Sustainable Development and Design Policy (2007) into four specific intents that could be analyzed using the descriptive statistics of the variables collected. Specifically, the policy will, for buildings falling under the LEED®-NC rating system, result in:

1. Reduced ownership costs through utility cost savings
2. Energy intensity reductions required by the EPAct of 2005 and EO 13423
3. Water intensity reductions required by EO 13423
4. An increase in the total facility construction costs of no more than two percent.

Item number one was analyzed using the "Utility Savings" variable. The second and third issues were studied using the "Energy Reduction," "Electricity Intensity Savings," "Fuel Intensity Savings," "Water Reduction," and "Water Intensity Savings" variables. Finally, the fourth point was evaluated using the "Green Premium." The "LEED Points Earned" variable is included for reference. Descriptive statistics of these variables are detailed in Table 3.

Table 3. SPSS generated descriptive statistics of the variables of interest.

		Utility Savings Per Square Foot (2003 $ / sq ft)	Energy Reduction (%)	Electricity Intensity Savings (kWh / sq ft)	Fuel Intensity Savings (kBtu /sq ft)	Water Reduction (%)	Water Intensity Savings (gal / sq ft)	Green Premium (%)	LEED Points Earned
N	Valid	93	160	79	66	160	83	47	160
	Missing	67	0	81	94	0	77	113	0
Mean		$ 0.7038	31.2%	6.2572	16.0700	26.6%	3.4830	0.0408	35.3
Std. Error of Mean		$ 0.1108	0.0124	0.9356	3.4840	0.0151	0.6660	0.0077	0.6150
Median		$ 0.3950	30.0%	3.8340	6.0800	30.0%	1.3313	0.0265	34
Mode		$ -	30.0%	0	0	30.0%	0	0.0101	33
Std. Deviation		1.0682	0.157	8.3155	28.3070	0.191	6.0678	0.0526	7.782
Variance		1.1410	0.025	69.1480	801.2780	0.036	36.8180	0.0030	60.564
Range		8.6072	80.0%	57.2584	152.0000	90.0%	32.8423	0.2727	34
Minimum		0	0.0%	0	0	0.0%	0	0.0011	26
Maximum		$ 8.6072	80.0%	57.2584	152.0000	90.0%	32.8423	0.2738	60
Percentiles	25	$ 0.2085	22.4%	1.6343	0	20.0%	0	0.0134	29
	50	$ 0.3950	30.0%	3.834	6.0800	30.0%	1.3313	0.0265	34
	75	$ 0.8083	40.2%	8.0574	16.7400	30.0%	3.3136	0.0392	39

The statistical analysis supports the premise that LEED® certified buildings will enjoy reduced operating costs over buildings designed to code. As the utility savings histogram in Appendix D and the associated percentiles above show, the median utility savings better captures the central tendency of the data set. Specifically, the mean savings for the buildings in this study was nearly at the 75th percentile or approximately $0.70 per square foot, but the median savings is only $0.40 per square foot.

EO 13423 requires new buildings to be constructed with energy conservation features consuming 30 percent less energy than the ASHRAE code, and it mandates an overall 30 percent energy intensity reduction by the year 2015 based on location-specific, 2003 baseline, energy intensity. While the energy reduction percentage awarded during LEED® certification offers a decent approximation of the first requirement, electricity and fuel intensities were included to help evaluate the second requirement. This enables engineers to use new building values to forecast base energy intensity changes. The current study's data suggest that LEED®-NC certified buildings have an average of 31

percent lower energy costs. As expected and as shown in Appendix D, the central tendency of the energy reduction, electricity intensity savings, and fuel intensity savings are distributed similarly to the utility savings above. Therefore, their central tendencies are also best represented by their median savings of 30 percent, 3.83 kWh per square foot, and 6.08 kBtu per square foot. As implied by the above utility cost savings, the data suggest that LEED® certification will enjoy energy intensity savings, but whether those savings will be large enough to meet the EO requirement is less certain. Looking only at the statistics, since the mean and median reduction fall around the 30 percent requirement, the data could be interpreted to suggest that around half of the time LEED® certification will result in meeting the EO requirement.

The distribution and conclusions concerning water intensity reductions are very similar to energy intensity reductions. Median water intensity savings of 1.3 gallons per square foot suggest LEED® certification will likely result in water conservation. However, assuming no requirement other than LEED® certification is specified, the average water reduction will likely be less than the EO mandate.

Unfortunately, only slightly more than 25 percent of the buildings reported enough information to calculate a green premium, and the available data was likely incomplete in such a manner that would lead to lower calculated premiums than the actual premium. However, the data still presents insight into the expected cost increases for incorporating sustainable design features. The mean premium was 4.08 percent, but for the same reasons mentioned above, the median of 2.65 percent is again a better representation of the central tendency of the data. Upon first glance, the median premium

seems relatively close to both the GSA suggested 2.5 percent and the USAF 2.0 percent authorization. However, when underreporting is considered, it would appear that the current Air Force policy does not allow for enough of a cost increase to successfully achieve LEED® certification. To put this in terms of money, the FY07 USAF military construction budget was $1.3 billion; 2 percent of that figure is $26 million (Gettle 2006). Evaluating this policy using statistics alone, it is likely that this $26 million sustainable design policy will fail to achieve its goals more often than it succeeds.

Trends in LEED®

The second research question compares previous studies to the current study's much larger, entirely LEED®-NC v2.0 and v2.1 certified sample of buildings. While the literature made numerous claims and cited various trends over the history of LEED®, this analysis is limited to just three issues.

1. The green premium variation with the number of LEED® points earned
2. The green premium variation over time
3. The cost per square foot variation with the number of LEED® points earned

To study issue one, we sorted the buildings by certification level, averaged the green premium for each level, and created a bar graph. For claim two, the average green premium each year for each LEED® certification level was graphed. To address the last issue, the cost per square foot and the number of LEED® points earned for each building was graphed.

In general, the effect of including only certified buildings has no effect on any of the three issues. As others have shown and intuition suggests, the green premium

increases as the number of LEED® points earned increases (see Figures 8, 9, and 10 below). However, the data in this study support the notion that the average value of the green premium for each certification level, which varies from 2.5 to 9.4 percent, is slightly larger than previous studies. Additionally, since the green premiums calculated in this paper are likely to be incomplete due to the lack of thorough reporting of green and sustainable design feature costs in the case studies, the values shown are likely smaller than the actual green premiums.

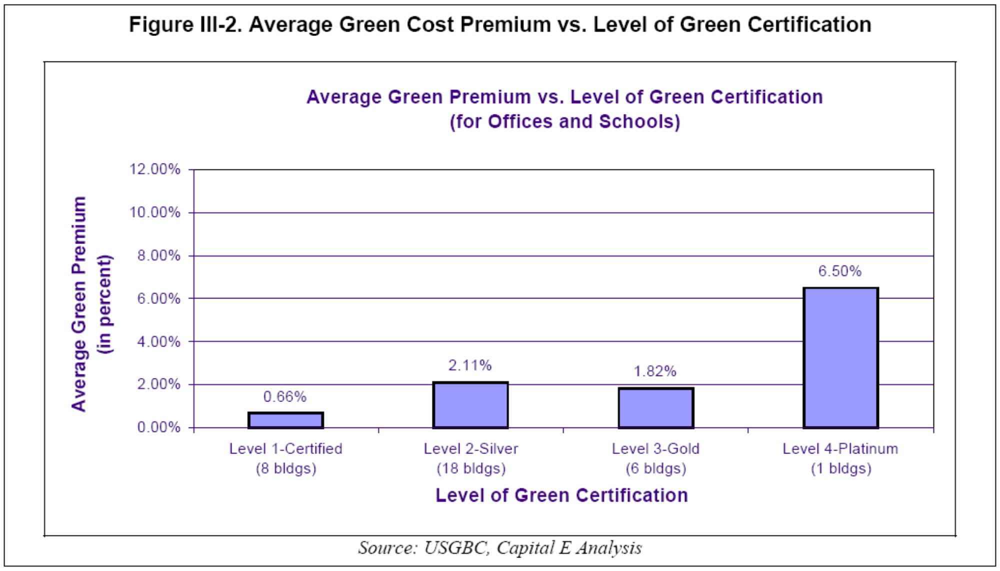


Figure 8. Green premium versus LEED® Certification Level (Kats et al. 2003)

	Platinum*	Gold*	Silver*
UCSB	7.8 %	2.7 %	1.0 %
San Francisco	7.8 %	2.7 %	1.0 %
Merced	10.3 %	5.3 %	3.7 %
Denver	7.6 %	2.8 %	1.2 %
Boston	8.8 %	4.2 %	2.6 %
Houston	9.1 %	6.3 %	1.7 %

Figure 9. Green premium versus LEED® certification level (Matthiessen & Morris 2004)

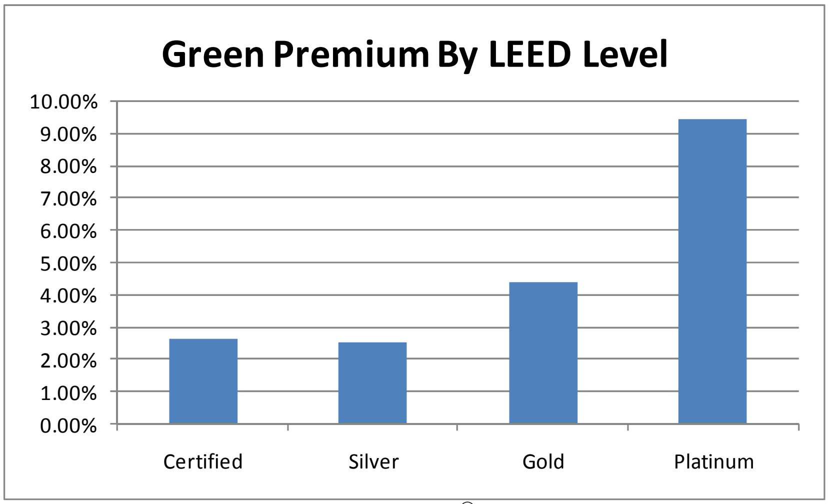


Figure 10. Green premium versus LEED® certification level, current study

Although Kats et al. (2003) reported, through interviews, that the green premium was decreasing over time, their own data, as shown in Figure 11 suggested that there was no such trend. The data in this study, shown in Figure 12, also seem to agree with the Kats et al. (2003) data. Although both figures reveal no trend whatsoever, this could be due in part to the incomplete nature of the calculated green premium.

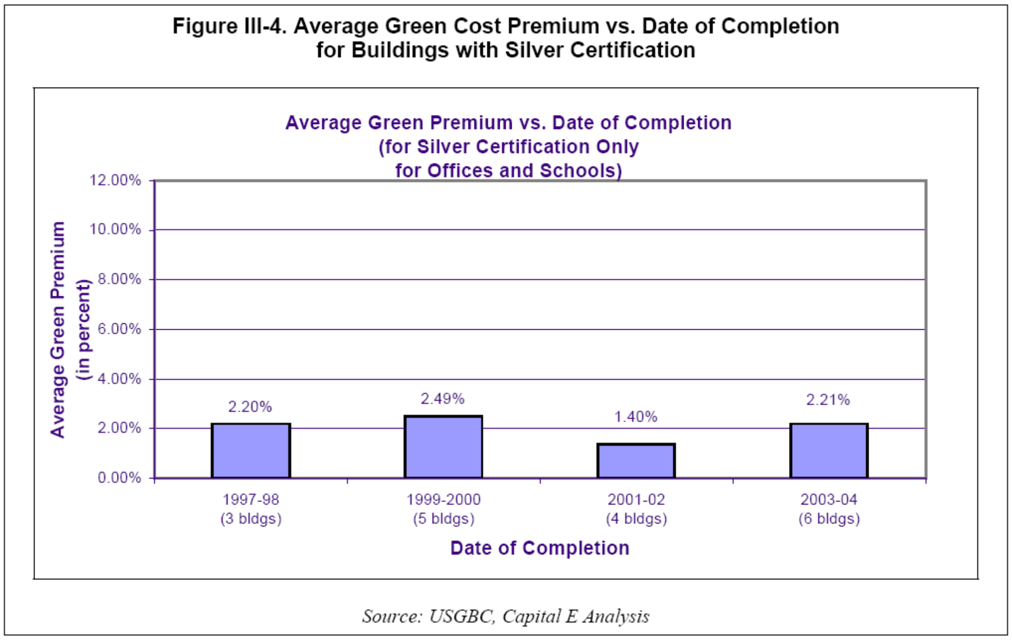


Figure 11. Green premium versus time (Kats et al. 2003)

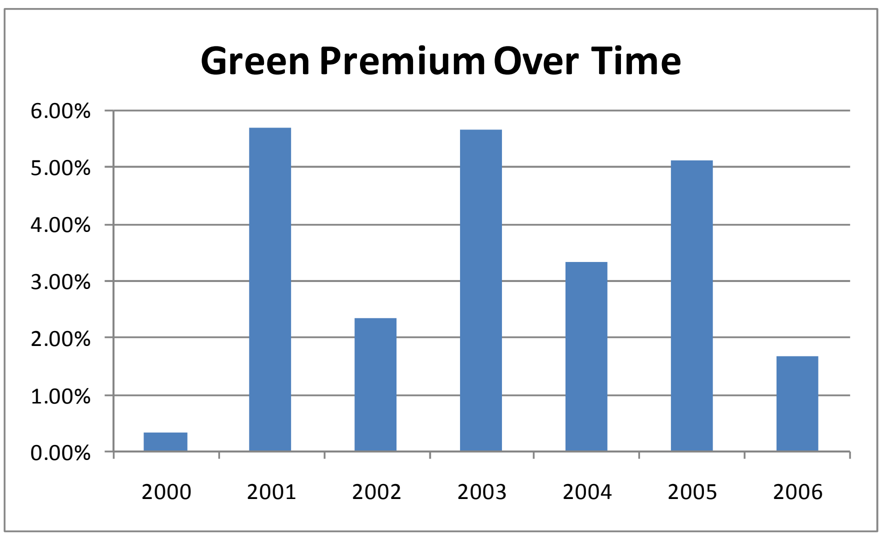


Figure 12. Green premium versus time, current study

Finally, the overall cost per square foot for the buildings in this study support the Matthiessen and Morris (2004, 2007) conclusion that the cost of incorporating sustainable design principles produces no more variation than any other construction scope decision.

To highlight the variation, we color coded our data by LEED® certification level. The similarity of this study's graphed data, shown in Figure 13, and the Matthiessen and Morris (2004) graphed data, shown in Figure 14, is striking. Additionally, since the current study's data was exclusively about LEED® certified buildings, the cost per square foot for each LEED® credit total was graphed, and this exposed the variation even among buildings achieving the same number of total credits. The graph is also color coded to highlight the various LEED® certification levels, and it is shown in Figure 15.

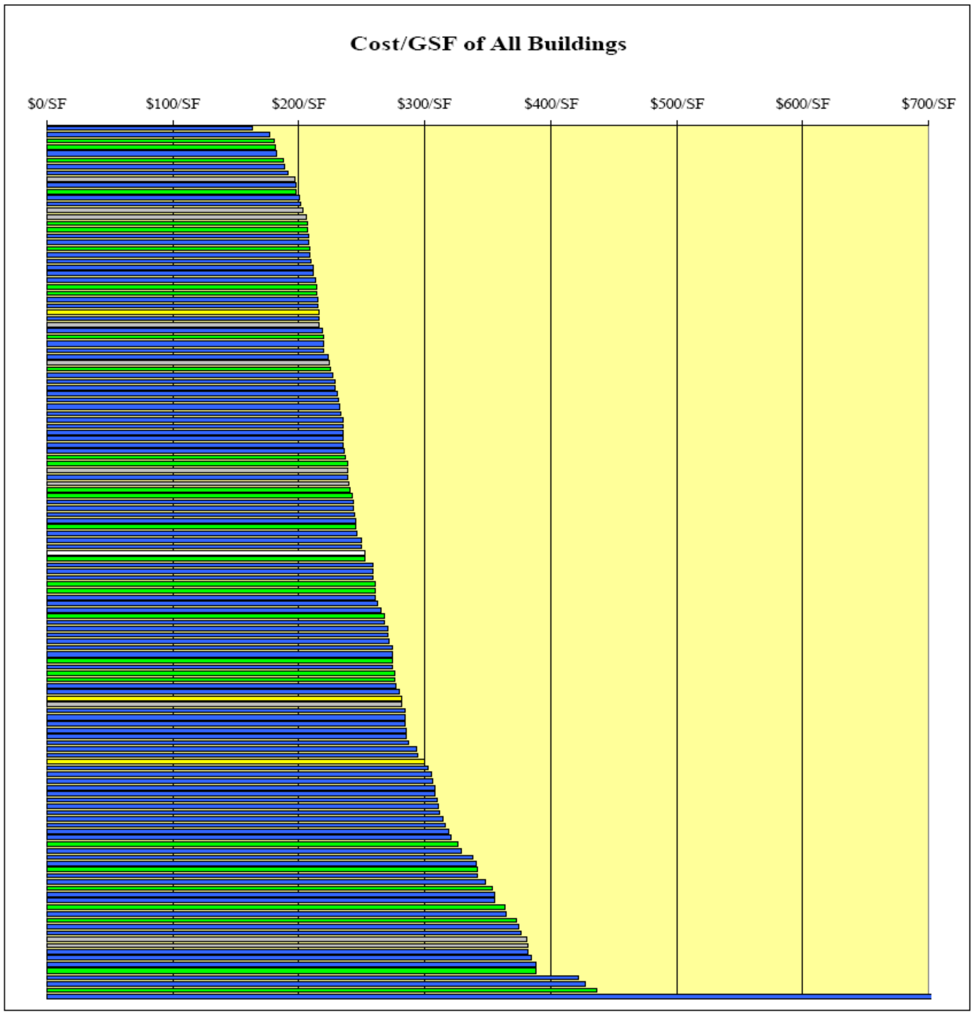


Figure 13. Cost per square foot (Matthiessen & Morris 2004)

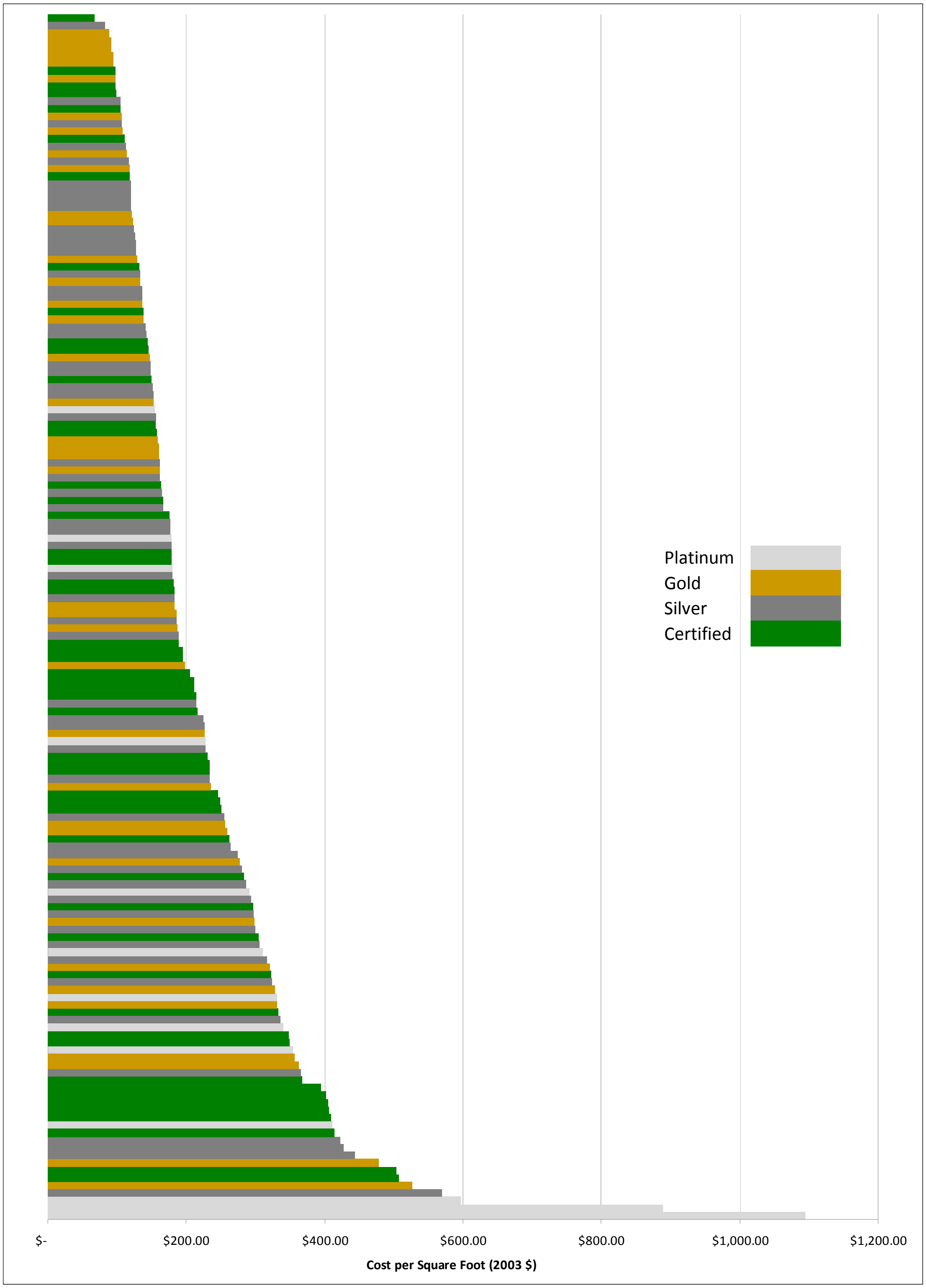


Figure 14. Cost per square foot, current study

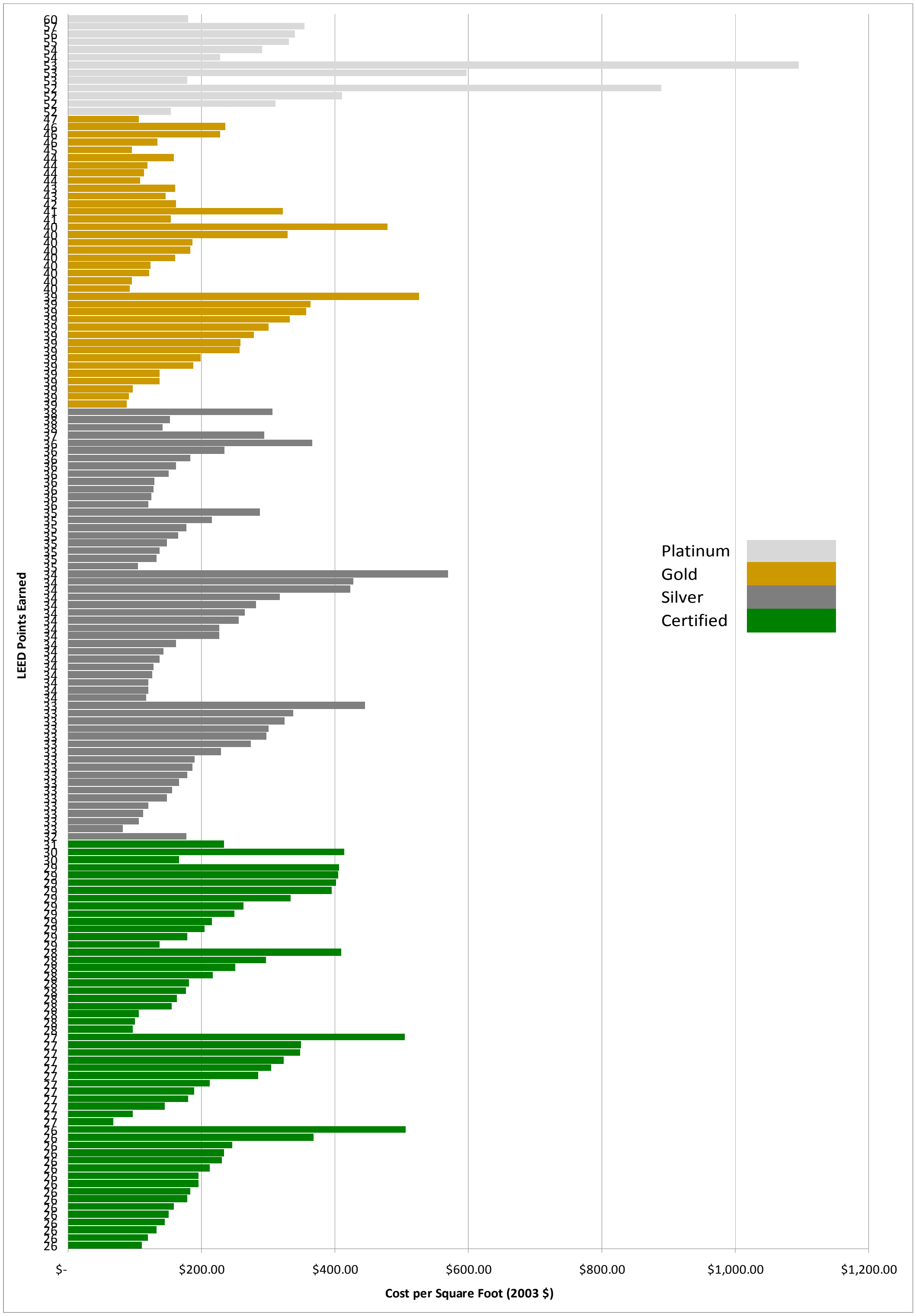


Figure 15. Cost per square foot, per LEED® credit total, current study

Correlations of Interest to the USAF

The final research question seeks significant trends that could help USAF civil engineers plan MILCON projects. It was assumed that USAF MILCON planners know the anticipated Cost per Square Foot, Region, Building Type, Construction Type, use of Onsite Renewable Energy Generation, and LEED® points sought. These variables were compared to the rest of the database using the correlation matrix to identify trends of significance (the complete correlation matrix is available in Appendix A). Correlations were highlighted if statistically significant at the 0.05 level or better, and if the correlation was moderate or greater using Mildred Patten's (2005) five point scale. She associates moderate correlation with a Pearson's correlation coefficient of at least 0.5 and strong correlation with a Pearson's correlation coefficient of 0.75 (Patten 2005).

The correlation matrix for this study revealed that the Cost per Square Foot, Region, Building Type, Construction Type, and Onsite Renewable Energy Generation were not correlated with any of the variables gathered at statistically significant, moderate level or greater (see Appendix A). LEED® Points Earned was moderately correlated with only Energy Reduction. Although moderately correlated with the commercial cost of electricity, the Green Premium was not correlated with Water Reduction, Energy Reduction, Utility Cost Savings, or LEED® Points Earned. The numerous cases with missing data likely influenced the lack of significant, strong correlations. Regardless, there are few, if any, correlations that USAF MILCON planners can utilize when designing future LEED® certified buildings.

V. Conclusions and Recommendations

Introduction

This study created the largest known, representative sample of LEED® certified buildings. Like earlier efforts, this study was hindered by grossly incomplete data, and the conclusions drawn were similar to previous studies. The analysis suggests that the USAF Sustainable Development and Design Policy will probably realize some of the directed and legal requirements it is intended to achieve. However, far more was learned about the relationship between construction variables and sustainability during the compilation of the database and the reflection on the results. The remainder of this paper is divided into three discussions. First, the laws and EOs pertaining to energy policy are described as being flawed, and then, why LEED® certification does not guarantee conservation or sustainable design is detailed. Finally, a conclusion is offered that the USAF needs to evaluate the focus of its sustainability policy and recommendations are provided for the road ahead.

Legal Intentions and Reality

It is arguable that, barring a significant economic reason to do so, the federal government would never incorporate energy and water conservation without a legal mandate. The EPAct of 2005 and EO 13423 represent both good and seemingly irrational ideas. For example, the notion of requiring new buildings and major renovations to meet higher conservation standards appears to be rooted in common sense.

However, the idea that an overall 30 percent reduction in energy intensity is even possible may be a bit ill conceived.

One of the major assumptions in evaluating LEED® is the idea that such a wide variety of building types could be compared. Structures that achieved certification include warehouses, industrial factories, office buildings, research facilities, and high-rise apartment buildings. Not surprisingly, the federal government also owns and occupies a wide variety of buildings, yet the intent of the law and EO is an overall, site-specific, 30 percent reduction in energy intensity. Seeing that supercomputers, wind tunnels, particle accelerators, and heated open spaces like hangars are unlikely to achieve this aggressive goal, it would appear that federal agencies will have to create massive savings in other buildings on the same installation. It is relatively obvious that the 31 percent average energy savings offered by LEED® certification will never be enough to make up for these energy intensive operations. Additionally, the increased use of devices like notebook computers, cellular phones, and personal digital assistants, with the associated huge energy losses from voltage and AC to DC conversion required to charge them, suggest the overall total federal energy consumption is only going to increase.

There are also laws that require historical building preservation, and it is equally unlikely that some of these facilities will ever achieve energy efficiency. For example, World War II era hangars at Elmendorf Air Force Base were protected as historical buildings, and as a result, the structures could not be truly modernized. Instead of producing arctic-efficient hangars, a series of multi-million dollar renovations returned the buildings to their 1950s structure including walls with no insulation and enormous

ceiling mounted, forced-air, natural gas heaters. Yet, Elmendorf Air Force Base was able to achieve the EO mandate by decommissioning its organic electricity generation. Even though there is little doubt that antiquated steam and electricity generation are inefficient, there will certainly be a time and place where these mandated energy efficiency will not mesh with other requirements.

The EPAct of 2005 requirement for metering all federal buildings is even more confusing. On the surface, it is a good idea; however, the law does not mandate reading the meters, and without such a requirement, it should be assumed that few, if any, agencies will use the devices to manage energy consumption. It is easy for federal agencies to alibi this failure since the law provided no funding for the required manpower to manage the meters, and future legislation should consider funding this manpower. However, perhaps this issue is a symptom of a greater problem. The nature of USAF operations and maintenance (O&M) funding gives senior leaders little motivation to allocate scarce resources towards saving money that cannot be spent in any other way. In other words, if a base does not use all of its O&M money, it does not get a credit towards buying something important like improved weapon systems. Instead, the USAF gets an O&M surplus that will be redirected to another base to fund O&M.

Yet legal requirements of efficiency have encouraged federal agencies to show some sign of compliance, and a comprehensive design program that is dedicated to sustainable design, such as LEED®, offers these agencies such a symbol. Organizations can claim that by using LEED®, they are at least trying to achieve the mandates.

However, there is rarely a one-size-fits-all program that is effective, and this study suggests that using LEED® design criteria may not be the best answer.

LEED® does not Equate to Sustainability or Conservation

LEED® certification is based on achieving a certain portion of the total number of possible credits, and as a result, certification does not guarantee much with regard to sustainability. For example, 12 of the 160 certified buildings in this study received no credits for energy reduction. Of those twelve, two were certified Silver, and one even incorporated ground source heat pumps. Additionally, 36 of the 160 buildings received no credits for water reduction, including 4 Gold and 14 Silver certified buildings. Building 70, a basic Certified structure, incorporated no renewable energy generation and received credits for neither water nor energy reduction. In other words, if the USAF wants to ensure it meets its legal obligations for energy and water conservation, it will have to include additional design requirements beyond those required for LEED® certification.

A large amount of attention has been focused on the initial cost of sustainable design. After gathering the data for this study, it appears that there are simply too many variables in construction to create an accurate model for the cost of achieving LEED® certification. Looking at the bigger picture however, the median cost for incorporating green for the buildings in this study was a mere $5 per square foot. Compared to other scope decisions like roofing, paint, or carpet options, few choices have the opportunity to offer any kind of payback. Additionally, sustainable design programs like LEED® encourage building commissioning, which has been shown to create direct cost savings.

For example, Mills (2004) studied 224 buildings and concluded that commissioning saved $1.24 a square foot in non-energy benefits like reduced change orders. However, the true paybacks of sustainable design are found in the indirect costs.

Unfortunately, the LEED® system does not ensure environmental externalities are factored into decisions and instead focuses on the operating cost bottom line. For the energy efficiency credits, points are awarded based on energy cost reduction percentages in relation to the ASHRAE and local codes. This can result in some environmentally unfortunate situations. EIA's electricity emissions data supports the notion that burning coal tends to create more pollution than burning natural gas (2006). However, in situations where electricity is less expensive than natural gas, a building's designers might achieve more energy reduction credits by increasing the energy proportion gained from electricity and reducing the natural gas consumed. For example, Georgia has the 8th most expensive commercial natural gas, but their predominantly coal generated electricity is only the 31st most expensive (EIA 2006). However, the savings in utility costs associated with choosing electricity over gas that result in LEED® credits are almost insignificant when compared with the total resulting externalities.

Previous studies have attempted to place value on these emissions based on the concept that air pollution varies levels that increase bothersome visibility and respiratory problems to levels that increase death rates (e.g., Tolley et al. 1984, Loehman et al. 1984, Farber & Rambaldi 1993). Yet most of these studies grossly underestimate the effects because it is difficult to determine where the externalities intersect. For example, when does pollution begin to affect crop production, ecosystem life cycles, or even weather?

Site considerations can help minimize the infrastructure required for storm water and contamination problems associated with runoff, which could result in making money set aside for infrastructure available for other public goods.

Additionally, while ideas like including bicycle racks and showers seem silly at first glance, at some point increased physical activity for employees likely leads to longer life and reduced health care costs. Studies about the effects of indoor environmental quality (IEQ) suggest workers will be sick less and thus able to work and reduce business inefficiency, but what about the fact that they might live longer too (Fisk 2000, Milton et al. 2000). The low volatile organic compound (VOC) paints associated with better IEQ affect not just the employees occupying the new building, but the workers who apply them during construction, the customers who visit, and the environment in which they are disposed. In order to capture the multitude of externalities, new data must be gathered, and new studies must be completed. The national benefits associated with these externalities are likely so large that discussing the benefits and costs associated with sustainable design without knowing their value is ill advised.

Sustainable Design Policy

If operating costs were the most concerning issue to the USAF, it would probably have taken a different approach to basing its forces in order to maximize utility savings by locating operations in low energy cost areas like Tennessee. However, the nature of national defense does not lend itself to determining base locations with energy costs, and though minimizing wasteful energy spending is important, it can never really drive USAF construction considerations. What is more important is focusing on how the indirect

benefits of incorporating sustainable design can create enormous benefits for the entire nation.

The USAF Sustainable Design and Development Policy, in addition to listing energy and water conservation goals, states that its intent is to "…reduce the environmental impact… and provide safe, healthy, and productive built environments" (Policy Letter 2007, p.1). However, the current study did not address sustainability as one of the primary goals of the USAF policy due to the lack of data necessary to measure sustainability. In order to generate the data recommended by Fowler et al. (2004) for studying sustainable design, it is imperative that government project managers gather, organize, and maintain detailed lists of construction costs in a manner that is both available and that can be managed by higher level organizations. After getting the costs documented, the benefits need to be addressed. While some environmental externality values may be generally transferable across the nation, many, as Rozen (2004) described, will not. As a result, every USAF installation needs to research and develop local values for many of the externalities associated with Air Force operations. When a more thorough value of the externalities associated with a specific USAF construction project can be determined, a complete value of the benefits of sustainable design can be calculated. The dollar value of these benefits, like Weber's (2004) Carnegie Mellon study, will likely be well into the millions of dollars, which would be more than ample justification for the added costs of sustainable design.

The Road Ahead

Given the current directives to reduce overall energy intensity, the USAF needs to adjust its policy. The current policy does not take into account the fact that the USAF is not replacing a sizable percentage of buildings on each base. Even if the USAF annually replaced 5 percent of buildings on every base with LEED® certified structures, the average 31 percent energy reduction will not even come close to meeting the EO requirement. Efforts to isolate and remove unnecessary, wasteful systems like the Elmendorf example above should be continued, but there needs to be a policy to address and aggressively fund energy renovations of existing buildings.

The requirement to meter all federal buildings described above offers the opportunity to identify some of the buildings with energy intensity problems that can be fixed, but as previously mentioned, a management program is required. A successful program will require the USAF to allocate already strained resources to develop it and personnel to manage it. However, with limited funding for energy efficient renovations and the majority of the easily identified problems fixed, there are few other viable options remaining.

The USAF has toiled to undo the environmental damages of the past, and the resulting benefit of having the environmental spotlight turned to other organizations is difficult to measure. However, the USAF is likely to maintain its concern about how daily operations impact natural surroundings, and as the world population continues to grow, there is little doubt that our dependence on energy and clean water will continue to be a significant issue. Combined with persistent Congressional budgetary oversight,

these factors emphasize the importance of basing policy decisions on solid economic analysis. While this paper has made simple conclusions related to sustainable design, it will hopefully spur further research. There is a multitude of economic research required to determine the benefits associated with externalities, and future management study should focus less on the cost of sustainable design and more on creating methods to prioritize renovations based on energy efficiency.

Appendix A—Building Database

The complete building database and correlation matrix are available in the attached compact disc. It is titled Nyikos 2007 Building Database.xls. This information is also available by contacting the author at david.nyikos@us.af.mil.

Appendix B—Quick Building Facts and Sources

Building ID	Name	City	ST	Floor Area (gross square feet)	Water Reduction (%)	Water Intensity Savings (gal / sq ft)	Energy Reduction (%)	Electricity Intensity (kWh / sq ft)	Fuel Intensity (kBtu / sq ft)	Renewable Energy Onsite	Total Construction Cost Per Square Foot (2003 $ / sq ft)	Utility Savings Per Square Foot (2003 $ / sq ft)	Green Premium (%)	LEED Points Earned	Source(s)
1	Homer Public Library	Homer	AK	17,000.00	20.0%		30.0%			No	$ 225.49			34	1
2	Homewood Middle School	Homewood	AL	180,000.00	40.0%		38.0%			No	$ 182.97			36	2, 3
3	Fayetteville Public Library	Fayetteville	AR	88,754.00	20.0%	1.96	20.0%			No	$ 255.71	$ 0.47	0.11%	34	4, 5
4	William J. Clinton Presidential Center	Little Rock	AR	282,000.00	23.0%	1.10	25.0%	5.85		PV	$ 569.93	$ 0.12		34	6
5	Apache Junction City Hall & Court Facility	Apache Junction	AZ	42,000.00	30.0%		0.0%			No	$ 150.29		5.00%	26	7, 8
6	South Rim Maintenance and Warehouse Facility	Grand Canyon	AZ	72,000.00	30.0%		20.0%			No	$ 195.01	$ 0.57		26	9, 10
7	Desert Broom Public Library	Phoenix	AZ	15,000.00	30.0%		20.0%			No	$ 194.81			26	11
8	First Mesa Elementary School & Housing	Polacca	AZ	74,744.00	30.0%		15.0%			No	$ 182.45			26	12
9	Kern Schools Federal Credit Union	Bakersfield	CA	144,000.00	30.0%		45.0%			No	$ 137.40			29	13
10	IEUA Headquarters	Chino	CA	66,000.00	73.0%		66.0%	14.33	1.61	PV	$ 154.00	$ 3.60		52	6
11	Edwards Consolidated Support Facility	Edwards AFB	CA	49,000.00	0.0%	0.00	30.0%			No	$ 228.61			33	14
12	Solano County Government Center	Fairfield	CA	342,000.00	0.0%	0.00	30.0%			PV	$ 233.55			31	15
13	Premier Automotive Group North American Headquarters	Irvine	CA	253,000.00	20.0%		30.0%			No	$ 246.39			26	6
14	Lake View Terrace Library	Lake View Terrace	CA	10,700.00	34.0%	9.05	60.0%			Solar	$ 411.21	$ 0.02		52	6
15	Audubon Center at Debs Park	Los Angeles	CA	5,023.00	70.0%	32.84	60.0%	4.34	2.33	PV & Solar	$ 1,094.96	$ 1.46	6.00%	53	16
16	Navy Building 850	Port Hueneme	CA	17,000.00	30.0%	1.55	55.0%			PV	$ 183.35	$ 0.39		40	16
17	Capitol Area East End Complex Block 225	Sacramento	CA	479,000.00	30.0%		45.0%			PV	$ 146.65	$ 0.40		43	17, 18
18	CalPERS Headquarters Complex	Sacremento	CA	550,000.00	0.0%	0.00	38.0%			PV	$ 328.89			40	19
19	West Valley Branch Library	San Jose	CA	20,000.00	0.0%	0.00	30.0%			No	$ 395.00			29	20
20	San Mateo County Forensics Laboratory	San Mateo	CA	28,975.00	30.0%		60.0%			PV	$ 414.15			30	21
21	Marine Science Research Building	Santa Barbara	CA	62,006.00	20.0%		25.0%	26.76	132.00	No	$ 367.99	$ 1.55		26	22, 23
22	Colorado Court Affordable Housing	Santa Monica	CA	30,150.00	0.0%	0.00	60.0%	0.70	38.81	PV	$ 158.56	$ 0.82		44	16
23	NRDC Santa Monica Office	Santa Monica	CA	15,000.00	63.0%	4.00	50.0%	3.46	15.73	PV	$ 340.00	$ 0.47	15.78%	56	6, 24

Building ID	Name	City	ST	Floor Area (gross square feet)	Water Reduction (%)	Water Intensity Savings (gal / sq ft)	Energy Reduction (%)	Electricity Intensity (kWh / sq ft)	Fuel Intensity (kBtu / sq ft)	Renewable Energy Onsite	Total Construction Cost Per Square Foot (2003 $ / sq ft)	Utility Savings Per Square Foot (2003 $ / sq ft)	Green Premium (%)	LEED Points Earned	Source(s)
24	Santa Monica Public Safety Facility	Santa Monica	CA	117,000.00	30.0%		45.0%			No	$ 366.64			36	25
25	Woodland Police Station	Woodland	CA	54,000.00	46.0%		30.0%			No	$ 216.46	$ 0.32		28	26, 27
26	Boulder Community Foothills Hospital	Boulder	CO	153,773.00	0.0%	0.00	30.0%			No	$ 296.54		2.93%	33	28, 29
27	North Boulder Recreation Center	Boulder	CO	61,700.00	0.0%	0.00	36.7%			Solar	$ 188.82	$ 0.91	4.86%	33	30, 31
28	Wolf Law Building	Boulder	CO	180,000.00	39.0%		35.0%			No	$ 234.77		1.01%	46	32
29	Colorado Springs Utility Laboratory	Colorado Springs	CO	47,943.00	30.0%		35.0%			No	$ 225.99	$ 0.98		34	33
30	Pikes Peak Regional Development Center	Colorado Springs	CO	111,758.00	30.0%		45.0%			No	$ 152.53			38	32
31	Department of Labor and Employment	Denver	CO	40,000.00	20.0%		20.0%			No	$ 97.41			28	32
32	City of Fort Collins Vehicle Storage Building	Fort Collins	CO	15,252.00	30.0%		50.0%			No	$ 148.25	$ 0.56		33	34
33	Fossil Ridge High School	Fort Collins	CO	296,375.00	0.0%	0.00	61.0%	4.39	14.34	No	$ 124.89	$ 0.77		36	34, 32, 35
34	NREL Science and Technology Facility	Golden	CO	71,347.00	20.0%		41.0%	38.10	91.90	No	$ 290.39	$ 2.26	3.57%	54	36
35	DOT Office Building	Lakewood	CO	129,000.00	0.0%	0.00	30.0%			No	$ 132.90			35	37
36	Mark Twain House Museum	Hartford	CT	32,700.00	20.0%		30.0%			No	$ 504.59			27	38, 39
37	SCSU New Residence Hall	New Haven	CT	120,726.00	20.0%		15.0%			No	$ 212.20			26	40, 41
38	National Association of Realtors Building	Washington	DC	102,000.00	30.0%		30.0%			No	$ 444.06			33	28
39	Sidwell Friends Middle School	Washington	DC	72,200.00	30.0%	2.76	60.0%	1.74	14.13	PV	$ 353.96	$ 0.48		57	6
40	Rinker Hall at the University of Florida	Gainesville	FL	47,270.00	30.0%	6.35	57.0%			No	$ 137.51	$ 0.46	2.88%	39	16
41	Library West	Gainesville	FL	177,000.00	30.0%		27.3%			No	$ 122.72			40	42
42	Mary Ann Coffrin-Harn Pavilion	Gainesville	FL	19,240.00	30.0%		35.0%			No	$ 262.47			29	42
43	McGuire Center for Lepidoptera and Biodiversity	Gainesville	FL	58,000.00	0.0%	0.00	25.0%			No	$ 119.24			26	42
44	UF Orthopaedics and Sports Medicine Institute	Gainesville	FL	132,663.00	30.0%		0.0%			No	$ 158.24			26	42
45	Powell Structures Lab	Gainesville	FL	8,565.00	0.0%	0.00	25.0%			No	$ 231.00			26	42
46	Veterinary Medicine Food Animal Facility	Gainesville	FL	9,997.00	0.0%	0.00	22.4%			No	$ 181.68			28	42

Building ID	Name	City	ST	Floor Area (gross square feet)	Water Reduction (%)	Water Intensity Savings (gal / sq ft)	Energy Reduction (%)	Electricity Intensity (kWh / sq ft)	Fuel Intensity (kBtu / sq ft)	Renewable Energy Onsite	Total Construction Cost Per Square Foot (2003 $ / sq ft)	Utility Savings Per Square Foot (2003 $ / sq ft)	Green Premium (%)	LEED Points Earned	Source(s)
47	UNF Social Sciences Building	Jacksonville	FL	63,000.00	30.0%		35.0%			No	$ 144.87		1.01%	26	43, 44
48	Balzer Theater at Herrens	Atlanta	GA	17,900.00	58.0%		25.0%	22.91		No	$ 293.85	$ 0.51		37	6
49	Management Building at Georgia Tech	Atlanta	GA	248,059.00	30.0%		15.0%	17.46	0.00	No	$ 161.25	$ 0.21		34	16
50	Mathematics and Science Center	Atlanta	GA	138,000.00	0.0%	0.00	20.0%			No	$ 296.46			28	45
51	Whitehead Biomedical Research Building	Atlanta	GA	325,000.00	30.0%		20.0%			No	$ 264.38			34	46
52	Forsyth County Family YMCA	Cumming	GA	54,751.00	37.0%	16.07	25.0%			No	$ 166.70	$ 0.52		33	47, 48
53	Southern Pine Conference Center	Pine Mountain	GA	54,000.00	30.0%		0.0%			No	$ 233.33			26	49
54	Hawaii Gateway Energy Center	Kailua-Kona	HI	3,600.00	30.0%	3.16	80.0%	12.62	0.00	PV & Sea Wat	$ 889.80	$ 8.61		52	6
55	Vermeer Science Center	Pella	IA	71,200.00	30.0%		20.0%			No	$ 280.90	$ 2.13		34	50, 51
56	Argonne National Lab Central Supply Facility	Argonne	IL	53,000.00	30.0%		30.0%	6.04	13.21	No	$ 127.42	$ 0.16	2.65%	36	52, 53, 54
57	Bolingbrook High School	Bolingbrook	IL	568,700.00	0.0%	0.63	25.0%			No	$ 155.64	$ 0.00		33	55, 56
58	Oriole Park Branch Library	Chicago	IL	14,000.00	0.0%	0.00	20.0%			No	$ 347.88			27	57
59	Wright Office Building	Darien	IL	35,000.00	30.0%		0.0%			No	$ 111.32			26	58, 59
60	Ford Motor Company Engineering Design Center	Evanston	IL	84,000.00	30.0%		25.0%			No	$ 336.48			33	60
61	Children's Discovery Museum	Normal	IL	34,000.00	0.0%	0.00	25.0%			No	$ 143.24			34	61
62	Isaac Ray Treatment Center	Logansport	IN	113,000.00	20.0%		20.7%			No	$ 177.59	$ 0.33		32	62
63	U.S. EPA Science and Technology Center	Kansas City	KS	71,955.00	30.0%		20.0%			No	$ 277.95			39	16
64	North American Production Support Center	Georgetown	KY	98,000.00	80.0%		0.0%	13.47		No	$ 111.76			33	63, 64
65	Artists for Humanity EpiCenter	Boston	MA	23,500.00	30.0%	1.33	65.0%	2.82	16.00	PV	$ 178.23	$ 1.08		53	6
66	Genzyme Center	Cambridge	MA	344,000.00	32.0%	1.57	42.0%	28.80		PV	$ 311.05	$ 2.20	27.38%	52	6, 65
67	Harvard Blackstone	Cambridge	MA	40,000.00	43.0%		35.0%			GSHP	$ 228.17			54	66
68	North Adams Public Library	North Adams	MA	27,270.00	0.0%	0.00	30.0%			PV & GSHP	$ 176.20		8.92%	28	67
69	Provincetown Art Association and Museum	Provincetown	MA	19,500.00	30.0%	3.12	45.0%	4.49	12.51	PV	$ 234.03	$ 0.54		36	6

Building ID	Name	City	ST	Floor Area (gross square feet)	Water Reduction (%)	Water Intensity Savings (gal / sq ft)	Energy Reduction (%)	Electricity Intensity (kWh / sq ft)	Fuel Intensity (kBtu / sq ft)	Renewable Energy Onsite	Total Construction Cost Per Square Foot (2003 $ / sq ft)	Utility Savings Per Square Foot (2003 $ / sq ft)	Green Premium (%)	LEED Points Earned	Source(s)
70	Unified Science Center	South Hadley	MA	191,000.00	0.0%	0.00	0.0%			No	$ 180.63	$ -		27	50, 68
71	Blair Towns	Silver Spring	MD	107,292.00	30.0%	8.19	20.0%	5.71	23.13	No	$ 96.93	$ 0.16	1.46%	27	16, 24
72	Eastern Village Cohousing Condominium	Silver Spring	MD	92,582.00	20.0%	0.42	44.0%	4.84	7.11	No	$ 126.20	$ 0.31		34	16
73	SSA Child Care Center	Woodlawn	MD	31,944.00	0.0%	0.00	28.0%	18.34	41.01	No	$ 163.29	$ 0.62		28	16
74	Caribou Weather Forecast Office (WFO)	Caribou	ME	8,375.00	30.0%	2.86	32.0%			No	$ 316.79	$ 0.01		34	16
75	Governor Baxter School for the Deaf	Falmouth	ME	9,160.00	30.0%		35.0%			No	$ 287.11			35	69, 70
76	John Mitchell Center	Gorham	ME	23,000.00	26.0%		30.0%			No	$ 214.66			29	56, 71
77	East End Elementary School	Portland	ME	67,700.00	30.0%		30.0%			No	$ 119.29			34	72
78	Detroit School of Arts	Detroit	MI	286,000.00	0.0%	0.00	25.0%	11.75	0.52	No	$ 401.89	$ 0.30		29	6
79	Bazzani Associates Headquarters	Grand Rapids	MI	9,480.00	30.0%	3.28	40.0%	2.62	22.36	No	$ 116.86	$ 0.24		34	6
80	West Side Health Center	Grand Rapids	MI	9,900.00	30.0%		10.0%			No	$ 322.67			27	73
81	Immaculate Heart of Mary Motherhouse	Monroe	MI	380,000.00	30.0%	2.06	0.0%	27.11	80.26	GSHP	$ 144.74	$ 0.00		27	6
82	Grand Valley State University MAREC	Muskegon	MI	26,000.00	49.2%	28.91	45.0%	10.65	29.19	PV	$ 226.92	$ 1.00		46	6
83	Herman Miller MarketPlace	Zeeland	MI	95,000.00	20.0%	1.32	45.0%	13.79	52.45	No	$ 91.03	$ 1.14		39	16
84	Westwood Elementary School	Zimmerman	MN	74,979.00	30.0%		50.0%			No	$ 155.89	$ 0.58	0.63%	28	74, 75
85	Alberici Corporate Headquarters	Overland	MO	109,000.00	70.0%	4.59	60.0%	7.14	9.54	Wind & Solar	$ 179.62	$ 0.80	2.55%	60	6
86	Earth and Planetary Sciences Building	St. Louis	MO	151,180.00	30.0%		30.0%			No	$ 284.14			27	50
87	US/Canada Shared Port of Entry	Sweet Grass	MT	100,000.00	21.8%		0.0%			No	$ 303.91			27	16
88	Fire Crash Rescue Station	Goldsboro	NC	6,750.00	20.0%		20.0%			No	$ 250.99			28	76
89	Third Creek Elementary	Statesville	NC	92,000.00	30.0%		25.0%	6.98	35.98	No	$ 97.27	$ 0.27		39	16, 77
90	U.S. EPA National Computer Center	Triangle Park	NC	101,000.00	0.0%	0.00	27.0%	20.79	411.21	PV	$ 215.05	$ 2.01	3.91%	35	16
91	Carl T Curtis National Park Service HQ	Omaha	NE	68,000.00	31.0%	2.70	25.0%	13.91	31.62	No	$ 121.76	$ 0.35		40	16
92	SPNHF--French Wing	Concord	NH	11,600.00	30.0%		55.0%	8.76	66.38	PV & Wood C	$ 107.48	$ 2.48	13.21%	44	16

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93	Willow School Phase 1	Gladstone	NJ	15,372.00	30.0%		25.0%			PV	$ 299.25	$ 0.08		39	69, 70, 78
94	St Joseph's School for the Blind	Jersey City	NJ	75,050.00	30.0%		25.0%			No	$ 249.57			29	79
95	Baca/Dlo'ay azhi Community School	Prewitt	NM	78,875.00	30.0%	2.55	20.0%			No	$ 131.85	$ 0.01	2.97%	26	16
96	Morse Arberry Jr. Telecommunication Building	North Las Vegas	NV	92,000.00	30.0%		30.0%			No	$ 166.23		3.29%	30	80
97	Heimbold Visual Arts Center	Bronxville	NY	60,000.00	24.0%	0.86	30.0%			GSHP	$ 405.86	$ 0.00	1.93%	29	6
98	Patrick H. Dollard Health Center	Harris	NY	28,300.00	0.0%	0.00	20.0%	6.54	0.00	GSHP	$ 212.01	$ 0.21	1.71%	27	6
99	Tompkins County SPCA	Ithaca	NY	14,630.00	35.0%	10.89	34.0%	15.04	28.16	No	$ 151.14	$ 3.12	5.09%	36	16
100	20 River Terrace The Solaire	New York	NY	356,787.00	50.0%	12.44	35.0%	8.31	93.27	PV	$ 320.89	$ 1.13	17.74%	41	16, 24
101	Tribeca Green	New York	NY	357,000.00	30.0%		20.0%			No	$ 197.93			39	28
102	Howard M. Metzenbaum US Courthouse	Cleavland	OH	235,600.00	32.4%		25.0%			No	$ 178.35			29	37
103	Jones Federal Building and Courthouse	Youngstown	OH	52,240.00	0.0%	0.00	22.5%	14.36	22.40	No	$ 349.61	$ 0.37	0.55%	27	16
104	Clackamas High School	Clackamas	OR	265,355.00	20.0%		50.0%	3.34	16.72	No	$ 119.67	$ 0.34		33	16
105	Sokol Blosser Winery Barrel Aging Cellar	Dundee	OR	5,805.00	0.0%	0.00	45.0%	1.32		No	$ 127.77	$ 0.12		34	16
106	Lillis Business Complex	Eugene	OR	137,000.00	0.0%	0.00	45.0%	6.34	38.25	PV	$ 299.27	$ 0.59	1.86%	33	6
107	Wayne L. Morse United States Courthouse	Eugene	OR	267,000.00	40.0%	5.94	30.0%	6.89	6.97	No	$ 256.38	$ 0.22	0.63%	39	16
108	Regional Training & Distribution Center	Gresham	OR	212,888.00	30.0%		40.0%			No	$ 87.85	$ 0.18	2.62%	39	81
109	Providence Newberg Medical Center	Newberg	OR	180,636.00	40.0%		20.0%			No	$ 356.72	$ 0.90	0.80%	39	81
110	Balfour-Gutherie Building	Portland	OR	19,000.00	30.0%		25.0%			No	$ 82.02			33	28
111	Gerding Theater at the Armory	Portland	OR	55,000.00	88.0%	14.13	30.0%	6.98	18.55	No	$ 597.40	$ 0.28		53	6
112	Jean Vollum Natural Capital	Portland	OR	70,000.00	30.0%		30.0%	12.69	0.66	No	$ 153.32	$ 0.35	4.20%	41	6
113	Oregon Health & Science University Center for Health & Healing	Portland	OR	400,000.00	60.0%	20.63	61.0%	6.48	28.57	PV & Solar	$ 330.85	$ 0.70	1.26%	55	24, 82
114	North Mall Office Building	Salem	OR	115,000.00	20.0%		45.0%			No	$ 187.83	$ 0.31	3.21%	39	81
115	The Plaza at PPL Center	Allentown	PA	280,000.00	45.0%	2.00	30.0%	18.46	6.40	No	$ 160.71	$ 0.71	3.45%	40	16

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116	DEP California Office Building	California	PA	21,190.00	41.0%		40.2%			No	$ 94.98			40	83
117	Felician Sisters Convent and School	Coraopolis	PA	161,000.00	0.0%	0.00	20.0%	10.94	29.22	PV & Solar	$ 136.65	$ 0.32	0.20%	39	6
118	DEP Cambria	Ebensburg	PA	36,000.00	30.0%	0.77	30.0%	11.75	0.00	PV	$ 94.92	$ 0.48	0.47%	45	16
119	Twin Valley Elementary School	Elverson	PA	70,163.00	30.0%		50.0%			No	$ 136.61			35	84
120	Clearview Elementary School	Hanover	PA	43,638.00	30.0%	3.50	40.0%	6.65	0.62	No	$ 161.44	$ 0.39		42	16, 77
121	Londonderry School	Harrisburg	PA	24,500.00	30.0%		0.0%			No	$ 99.39			28	84
122	DEP Southeast Regional Office Building	Norristown	PA	110,700.00	83.0%		40.7%			No	$ 105.87			47	83
123	Children's Museum of Pittsburgh	Pittsburgh	PA	80,000.00	30.0%		10.0%			PV	$ 273.95	$ 0.00	1.34%	33	85, 86, 87
124	David L. Lawrence Convention Center	Pittsburgh	PA	1,486,000.00	75.0%	5.52	35.6%			No	$ 259.08	$ 0.78		39	85
125	Heinz Regional History Center	Pittsburgh	PA	74,000.00	0.0%	0.00	25.0%			No	$ 136.37			34	85
126	McGowan Institute	Pittsburgh	PA	45,200.00	30.0%		30.0%			No	$ 331.86			39	85, 88
127	New House Residence Hall	Pittsburgh	PA	71,140.00	0.0%	0.00	33.0%	10.15	20.09	No	$ 176.41	$ 0.52	1.94%	35	85, 89
128	Phipps Conservancy and Botanical Gardens Welcome Center	Pittsburgh	PA	12,465.00	30.0%		20.0%			No	$ 423.02			34	85
129	Pittsburgh Glass Center	Pittsburgh	PA	17,600.00	0.0%	0.00	27.0%			No	$ 92.05			40	6, 85
130	PNC Firstside Center	Pittsburgh	PA	647,000.00	0.0%	0.00	30.0%	29.06	0.09	No	$ 178.26	$ 1.07	0.23%	33	16, 90
131	Posner Center	Pittsburgh	PA	11,400.00	0.0%	0.00	20.0%			No	$ 506.51			26	85
132	WYEP Radio Station	Pittsburgh	PA	19,084.00	30.0%		15.0%			No	$ 129.13			36	85, 91
133	McGinnis Education Center	Sharpsburg	PA	12,000.00	30.0%		55.0%			No	$ 141.32			38	85, 92
134	Lower Windsor Township Community Center	Wrightsville	PA	37,100.00	59.0%		60.0%			GSHP	$ 105.02			35	83
135	Wrightsville Elementary School	Wrightsville	PA	80,400.00	20.0%		35.0%			PV	$ 120.00	$ 0.00		34	69, 83, 84
136	West Quad Living-Learning Center	Columbia	SC	180,000.00	20.0%		45.0%			Solar	$ 161.73			36	93
137	North Charleston Elementary School	North Charleston	SC	89,000.00	30.0%		40.0%			No	$ 119.65	$ 0.64		36	94
138	ORNL East Campus Private Development	Oak Ridge	TN	376,052.00	0.0%	0.00	25.0%	27.39	50.39	No	$ 189.71	$ 0.75		27	16

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139	IBM Tivoli Systems	Austin	TX	200,000.00	0.0%	0.00	27.0%			No	$ 178.99		3.00%	26	6, 95
140	Jack Evans Police Headquarters	Dallas	TX	359,000.00	21.0%	6.44	45.0%	20.06	11.25	No	$ 164.35	$ 1.37	2.97%	35	6
141	Scowcroft Building	Ogden	UT	104,569.00	20.0%	2.07	25.0%	8.56	43.51	No	$ 106.59	$ 0.24		33	16
142	Langston High School	Arlington	VA	50,300.00	23.0%	3.31	17.0%			No	$ 148.01	$ 0.20		35	6
143	One and Two Potomac Yard	Arlington	VA	654,000.00	42.0%	3.23	25.0%	10.87	0.00	No	$ 160.01	$ 0.22	3.57%	43	16, 96
144	Personnel Support Facility Little Creek	Virginia Beach	VA	37,800.00	50.0%	13.52	27.4%	10.16	16.97	No	$ 186.05	$ 0.31		33	16
145	ECHO	Burlington	VT	30,000.00	30.0%		35.0%	11.43	30.07	No	$ 333.33	$ 0.82		29	16
146	Wind NRG Partners Manufacturing Facility	Hinesburg	VT	46,500.00	43.5%	2.43	60.0%	3.12	11.03	PV & Wind &	$ 113.95	$ 0.86	13.38%	44	16
147	Island Wood	Bainbridge Island	WA	70,600.00	80.0%		25.0%			PV & Solar	$ 478.07	$ 0.02		40	6
148	Bremerton BEQ Building 1044	Bremerton	WA	99,786.00	0.0%	0.00	34.0%	12.03	5.23	No	$ 204.99	$ 0.39	1.52%	29	16
149	Issaquah Highlands Fire Station #73	Issaquah	WA	11,427.00	30.0%		0.0%			No	$ 306.29		2.94%	38	97
150	Seminar II The Evergreen State College	Olympia	WA	168,000.00	30.0%	1.84	25.0%			No	$ 185.54	$ 0.00		40	6
151	King County Kent Pullen Regional Communications & Emergency Coordination Center	Renton	WA	34,900.00	0.0%	0.00	25.0%			No	$ 409.74			28	98
152	Seattle Terminal Radar Approach Control	SeaTac	WA	52,115.00	33.0%	4.73	15.0%			No	$ 526.72	$ 0.01		39	16, 99
153	Alcyone	Seattle	WA	201,000.00	25.0%	2.94	0.0%	3.27	3.62	No	$ 67.84	$ 0.01		27	6
154	Fisher Pavilion	Seattle	WA	24,000.00	50.0%	14.58	0.0%	19.08	12.68	No	$ 404.85	$ 0.03		29	6
155	Seattle Central Library	Seattle	WA	362,987.00	25.0%	3.17	30.0%	17.35	16.49	No	$ 427.21	$ 0.76		34	100, 101
156	Seattle City Hall	Seattle	WA	198,000.00	30.0%		30.0%			No	$ 363.64	$ 0.26	1.41%	39	81
157	Seattle Justice Center	Seattle	WA	288,000.00	0.0%	0.00	35.0%	16.56	21.33	No	$ 324.42	$ 0.37	1.93%	33	16, 101, 102
158	Seattle Park 90-5 Building C	Seattle	WA	172,000.00	49.0%	2.97	30.0%	7.76	3.61	No	$ 118.26	$ 0.21		44	102, 103
159	Traugott Terrace	Seattle	WA	38,500.00	39.0%	6.18	26.0%	6.00	108.57	No	$ 105.61	$ 0.41		28	6, 102
160	Wisconsin DNR Green Bay Headquarters	Green Bay	WI	34,600.00	30.0%	2.60	60.0%	8.87	22.60	No	$ 133.42	$ 1.21	1.45%	46	6

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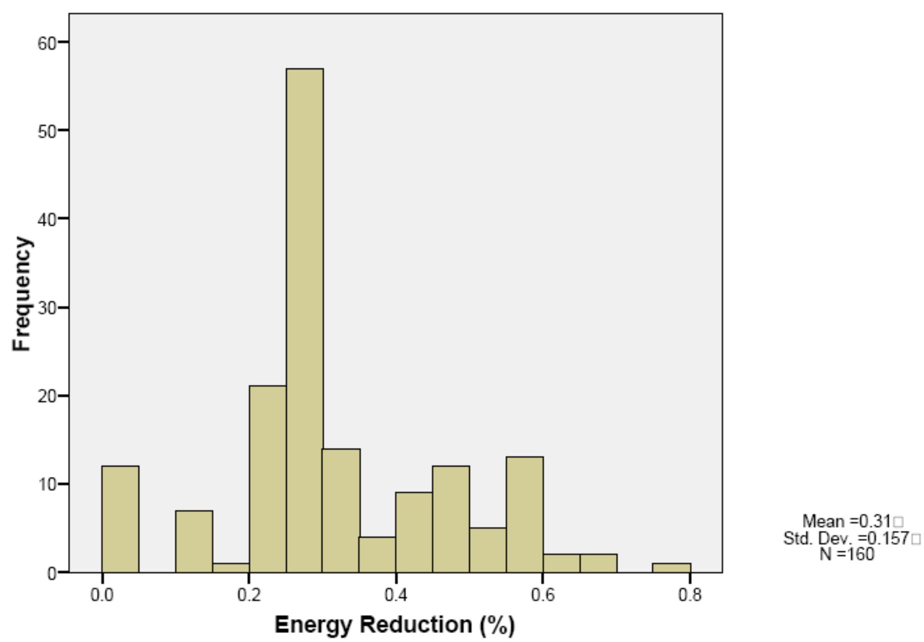
Appendix C—2003 Energy Information Administration State Energy Data

Regional Assignment | 2003 Electricity and Emissions Data | 2003 Natural Gas

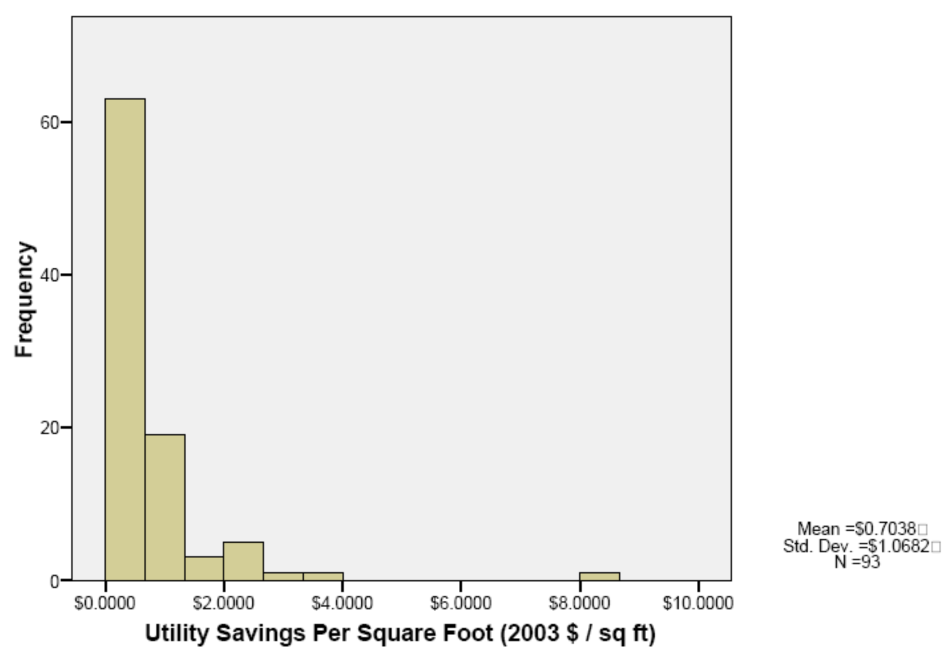
State	NERC Region	Census Region	Cesus Sub Region	NOAA Region	Primary Fuel Source	Total Retail Sales		Full Service Sales (including unregulated generators)		Energy Service Providers		Direct Use		All Sectors Average Retail Price		Commercial Average Retail Price		Total Summer Capacity		Net Generation		Sulfur Dioxide Emissions		Nitrogen Oxide Emissions		Carbon Dioxide Emissions		Commercial Average Retail Price	
						MWh	Rank	MWh	Rank	MWh	Rank	MWh	Rank	$/kWh	Rank	$/kWh	Rank	MW	Rank	MWh	Rank	k m tons	Rank	k m tons	Rank	k m tons	Rank	$/kBtu	Rank
AK	NA	West	Pacific	Alaska	Gas	5,563,682	50	5,563,682	49	0	0	1,077,994	30	$0.1050	7	$0.1049	5	1,895	48	6,338,732	48	5	48	8	47	3,944	46	$ 0.0034	51
AL	SERC	South	East South Central	South	Coal	83,844,220	15	83,844,220	15	0	0	6,481,099	5	$0.0588	40	$0.0685	27	30,162	10	137,487,223	8	453	9	152	8	80,325	9	$ 0.0097	11
AR	SERC	South	West South Central	South	Coal	43,108,259	30	43,108,259	30	0	0	2,393,069	20	$0.0557	44	$0.0554	49	13,549	27	50,401,101	27	79	29	46	34	27,220	32	$ 0.0073	38
AZ	WECC	South	West South Central	West	Coal	64,079,560	23	64,079,560	22	0	0	373,797	39	$0.0734	17	$0.0709	24	23,510	15	94,396,217	16	63	31	80	22	46,655	20	$ 0.0076	35
CA	WECC	West	Pacific	West	Gas	238,709,728	2	172,746,724	3	65,963,004	1	15,183,496	3	$0.1162	3	$0.1219	3	57,850	2	192,788,544	4	17	42	60	31	55,855	16	$ 0.0105	5
CO	WECC	West	Mountain	Central	Coal	46,494,645	27	46,494,645	26	0	0	495,263	35	$0.0677	24	$0.0660	33	10,370	32	46,616,788	30	70	30	71	26	40,599	24	$ 0.0081	24
CT	NPCC	Northeast	New England	East	Nuclear	31,830,218	33	31,230,118	33	600,100	16	1,539,033	24	$0.1016	9	$0.0993	10	7,573	34	29,545,050	40	8	46	11	45	9,534	40	$ 0.0053	49
DC	RFC	South	South Atlantic	East	Petroleum	10,946,383	45	5,725,475	48	5,220,908	11	384	50	$0.0740	16	$0.0735	19	806	51	74,144	51 *		50 *		51	82	50	$ 0.0127	2
DE	RFC	South	South Atlantic	East	Coal	12,599,590	42	10,488,250	42	2,111,340	13	563,430	34	$0.0696	19	$0.0731	20	3,392	44	7,392,288	47	36	37	13	41	6,996	45	$ 0.0087	17
FL	FRCC	South	South Atlantic	South	Gas	217,378,622	3	217,378,622	2	0	0	6,902,953	4	$0.0772	14	$0.0713	23	49,419	3	212,610,010	2	468	8	257	2	128,796	2	$ 0.0104	6
GA	SERC	South	South Atlantic	South	Coal	123,676,657	8	123,676,657	6	0	0	5,556,906	6	$0.0632	32	$0.0666	31	34,815	7	124,076,834	11	586	5	121	14	79,356	10	$ 0.0100	8
HI	NA	West	Pacific	Pacific	Petroleum	10,390,836	47	10,390,836	44	0	0	480,116	36	$0.1447	1	$0.1502	1	2,268	47	10,976,371	44	23	39	13	42	8,545	42	$ 0.0192	1
IA	MRO	Midwest	West North Central	Central	Coal	41,207,284	31	41,207,284	31	0	0	1,350,833	27	$0.0611	36	$0.0624	37	10,074	33	42,116,191	33	139	21	78	24	40,616	23	$ 0.0076	32
ID	WECC	West	Mountain	West	Hydro	21,218,685	38	21,218,685	38	0	0	710,470	31	$0.0522	48	$0.0556	48	3,002	45	10,422,937	45	6	47	3	48	1,103	49	$ 0.0064	47
IL	SERC	Midwest	East North Central	Central	Nuclear	136,247,891	7	115,070,513	8	21,177,378	4	4,275,912	10	$0.0686	21	$0.0730	21	45,541	4	189,055,258	5	372	11	144	9	94,941	6	$ 0.0082	22
IN	RFC	Midwest	East North Central	Central	Coal	100,467,779	12	100,467,779	10	0	0	4,755,661	7	$0.0537	47	$0.0612	38	25,641	14	124,888,218	10	744	3	248	4	116,590	5	$ 0.0085	19
KS	SPP	Midwest	West North Central	Central	Coal	36,735,390	32	36,735,390	32	0	0	62,101	49	$0.0635	30	$0.0642	34	10,876	31	46,567,560	31	128	23	86	19	38,463	26	$ 0.0080	25
KY	SERC	South	East South Central	Central	Coal	85,219,631	14	85,219,631	14	0	0	188,286	43	$0.0442	51	$0.0537	51	19,068	20	91,718,820	19	483	7	169	7	85,573	8	$ 0.0081	23
LA	SERC	South	West South Central	South	Gas	77,769,322	17	77,769,322	16	0	0	22,048,053	2	$0.0693	20	$0.0742	17	25,749	13	94,885,041	14	194	20	96	15	55,863	15	$ 0.0085	20
MA	NPCC	Northeast	New England	East	Gas	55,514,357	25	45,775,113	27	9,739,244	9	2,452,982	18	$0.1056	6	$0.1048	6	13,877	26	48,385,024	29	82	28	33	37	27,197	33	$ 0.0109	3
MD	RFC	South	South Atlantic	East	Coal	71,258,583	21	59,692,937	24	11,565,646	6	1,197,044	28	$0.0645	28	$0.0695	26	12,472	29	52,244,238	26	264	14	69	29	32,632	29	$ 0.0080	28
ME	NPCC	Northeast	New England	East	Gas	11,971,837	43	768,781 51	1	1,203,056	7	4,367,847	9	$0.0979	10	$0.1034	7	4,285	42	18,971,638	43	20	41	11	44	7,662	43	$ 0.0109	4
MI	RFC	Midwest	East North Central	Central	Coal	108,877,193	10	98,765,181	12	10,112,012	8	2,919,243	16	$0.0685	23	$0.0755	16	30,450	9	111,347,059	12	364	12	130	12	73,278	12	$ 0.0066	46
MN	MRO	Midwest	West North Central	Central	Coal	63,087,339	24	63,087,339	23	0	0	2,928,218	15	$0.0601	39	$0.0612	39	11,485	30	55,050,997	25	113	24	94	16	39,637	25	$ 0.0076	33
MO	SERC	Midwest	West North Central	Central	Coal	74,239,888	20	74,239,888	19	0	0	304,828	41	$0.0602	38	$0.0578	43	19,977	19	87,225,088	20	258	16	136	11	75,640	11	$ 0.0083	21
MS	SERC	South	East South Central	South	Coal	45,543,881	28	45,543,881	28	0	0	2,382,755	21	$0.0646	27	$0.0725	22	17,282	23	40,148,279	34	86	26	47	32	23,428	34	$ 0.0079	30
MT	WECC	West	Mountain	West	Coal	12,824,660	41	10,282,211	45	2,542,449	12	155,230	45	$0.0614	35	$0.0685	28	5,210	40	26,268,727	41	23	40	37	36	18,659	38	$ 0.0067	45
NC	SERC	South	South Atlantic	East	Coal	121,335,121	9	121,335,121	7	0	0	4,091,493	12	$0.0686	22	$0.0665	32	27,263	12	127,582,318	9	450	10	138	10	71,977	13	$ 0.0094	14
ND	MRO	Midwest	West North Central	Central	Coal	10,461,108	46	10,461,108	43	0	0	166,558	44	$0.0547	45	$0.0564	46	4,663	41	31,322,129	38	128	22	70	28	31,770	30	$ 0.0068	44
NE	MRO	Midwest	West North Central	Central	Coal	25,856,566	36	25,856,566	36	0	0	72,037	46	$0.0564	43	$0.0581	42	6,684	36	30,455,984	39	63	32	46	33	21,376	36	$ 0.0069	42
NH	NPCC	Northeast	New England	East	Nuclear	10,972,542	44	10,824,276	41	148,266	17	455,577	37	$0.1083	5	$0.1030	8	4,244	43	21,597,105	42	52	33	10	46	7,600	44	$ 0.0097	10
NJ	RFC	Northeast	Middle Atlantic	East	Nuclear	76,382,512	19	69,668,164	20	6,714,348	10	2,404,390	19	$0.0948	11	$0.0911	11	18,647	21	57,399,351	24	49	34	32	38	20,194	37	$ 0.0089	16
NM	WECC	West	Mountain	South	Coal	19,330,491	39	19,330,491	39	0	0	445,381	38	$0.0700	18	$0.0736	18	6,288	38	32,735,653	37	46	36	71	27	31,158	31	$ 0.0068	43
NV	WECC	West	Mountain	West	Coal	30,131,660	34	30,131,660	34	0	0	232,260	42	$0.0829	12	$0.0879	12	7,508	35	33,194,889	36	47	35	40	35	22,982	35	$ 0.0072	39
NY	NPCC	Northeast	Middle Atlantic	East	Nuclear	144,044,703	5	100,387,510	11	43,657,193	2	4,216,899	11	$0.1244	2	$0.1293	2	36,696	6	137,643,315	7	259	15	81	21	56,944	14	$ 0.0101	7
OH	RFC	Midwest	East North Central	East	Coal	152,189,238	4	127,249,081	5	24,940,157	3	1,486,344	25	$0.0673	25	$0.0755	15	34,060	8	146,638,129	6	1141	1	335	1	127,703	3	$ 0.0079	29
OK	SPP	South	West South Central	South	Coal	50,428,168	26	50,428,168	25	0	0	1,152,560	29	$0.0635	31	$0.0638	35	18,238	22	60,626,856	22	110	25	86	18	48,521	18	$ 0.0080	26
OR	WECC	West	Pacific	West	Hydro	45,194,730	29	45,194,730	29	0	0	690,673	32	$0.0618	34	$0.0638	36	12,883	28	48,966,138	28	13	44	12	43	8,765	41	$ 0.0076	34
PA	RFC	Northeast	Middle Atlantic	East	Coal	140,369,128	6	127,963,731	4	12,405,397	5	4,478,416	8	$0.0802	13	$0.0862	13	42,368	5	206,349,516	3	912	2	177	6	119,184	4	$ 0.0091	15
RI	NPCC	Northeast	New England	East	Gas	7,796,626	49	7,096,649	47	699,977	15	64,968	48	$0.1047	8	$0.1009	9	1,734	49	5,621,146	50	1	49	1	49	2,398	48	$ 0.0099	9
SC	SERC	South	South Atlantic	East	Nuclear	77,054,098	18	77,054,098	17	0	0	2,041,837	22	$0.0608	37	$0.0681	29	20,659	18	93,772,678	17	207	19	78	25	36,658	27	$ 0.0095	12
SD	MRO	Midwest	West North Central	Central	Hydro	9,079,990	48	9,079,990	46	0	0	0	0	$0.0635	29	$0.0604	41	2,690	46	7,943,837	46	12	45	15	40	3,649	47	$ 0.0070	40
TN	SERC	South	East South Central	South	Coal	97,455,808	13	97,455,808	13	0	0	3,389,262	13	$0.0584	42	$0.0668	30	20,893	17	92,221,791	18	344	13	129	13	55,820	17	$ 0.0086	18
TX	TRE	South	West South Central	South	Gas	322,685,955	1	322,685,955	1	0	0	41,705,982	1	$0.0750	15	$0.0784	14	99,594	1	379,199,685	1	614	4	252	3	254,955	1	$ 0.0074	37
UT	WECC	Northeast	New England	West	Coal	23,860,350	37	23,860,350	37	0	0	360,206	40	$0.0541	46	$0.0559	47	5,797	39	38,023,666	35	32	38	68	30	34,423	28	$ 0.0055	48
VA	SERC	South	South Atlantic	East	Coal	101,509,731	11	101,479,128	9	30,603	18	2,995,409	14	$0.0627	33	$0.0574	44	21,258	16	75,309,421	21	237	17	79	23	46,125	21	$ 0.0094	13
VT	NPCC	Northeast	New England	East	Nuclear	5,352,429	51	5,352,429	50	0	0	70,908	47	$0.1098	4	$0.1129	4	997	50	6,027,961	49 *		51 *		50	25	51	$ 0.0077	31
WA	WECC	West	Pacific	West	Hydro	78,133,501	16	76,112,939	18	2,020,562	14	1,392,566	26	$0.0586	41	$0.0607	40	27,689	11	100,094,691	13	16	43	26	39	14,984	39	$ 0.0069	41
WI	MRO	Midwest	East North Central	Central	Coal	67,241,494	22	67,241,494	21	0	0	2,755,932	17	$0.0664	26	$0.0697	25	14,309	25	60,122,425	23	232	18	94	17	48,410	19	$ 0.0080	27
WV	RFC	South	South Atlantic	East	Coal	28,296,993	35	28,296,993	35	0	0	1,816,264	23	$0.0513	49	$0.0545	50	16,124	24	94,711,553	15	508	6	194	5	85,676	7	$ 0.0075	36
WY	WECC	West	Mountain	Central	Coal	13,253,836	40	13,253,836	40	0	0	661,603	33	$0.0476	50	$0.0574	45	6,562	37	43,626,602	32	84	27	81	20	45,319	22	$ 0.0052	50

Appendix D—Histograms

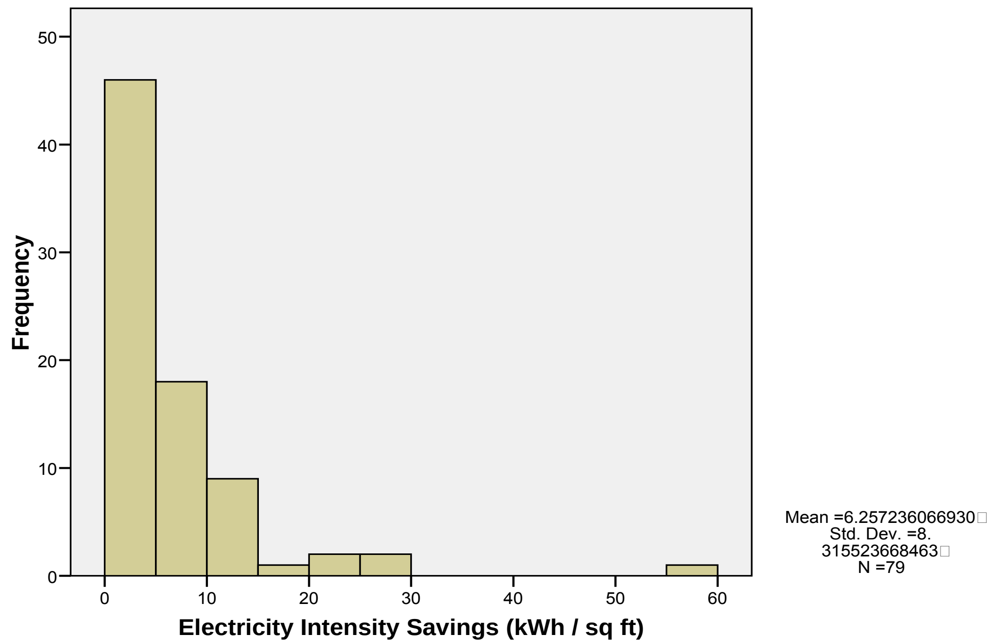
Energy Reduction (%)



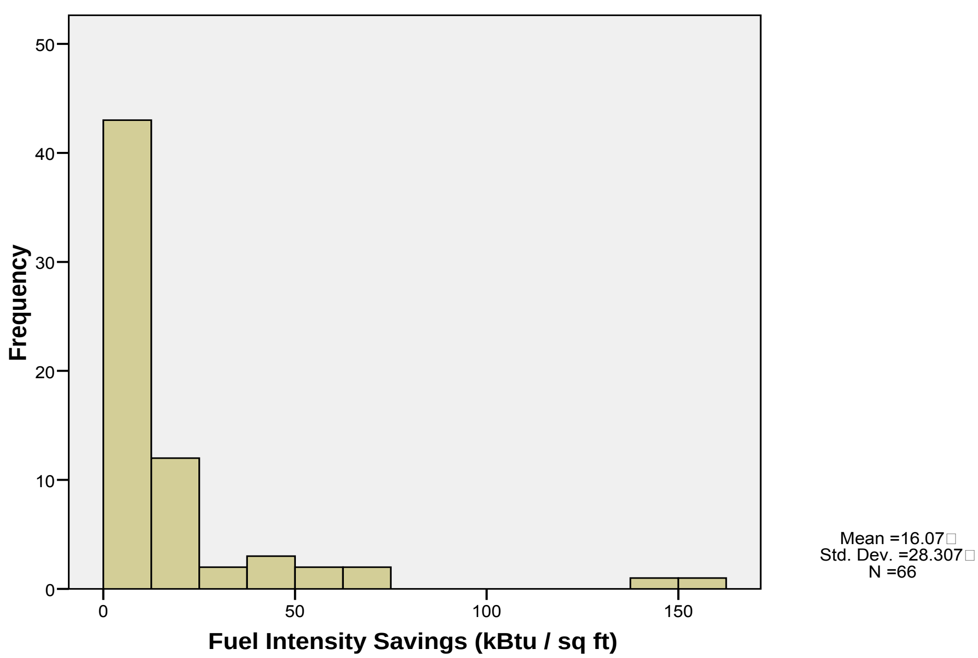
Utility Savings Per Square Foot (2003 $ / sq ft)



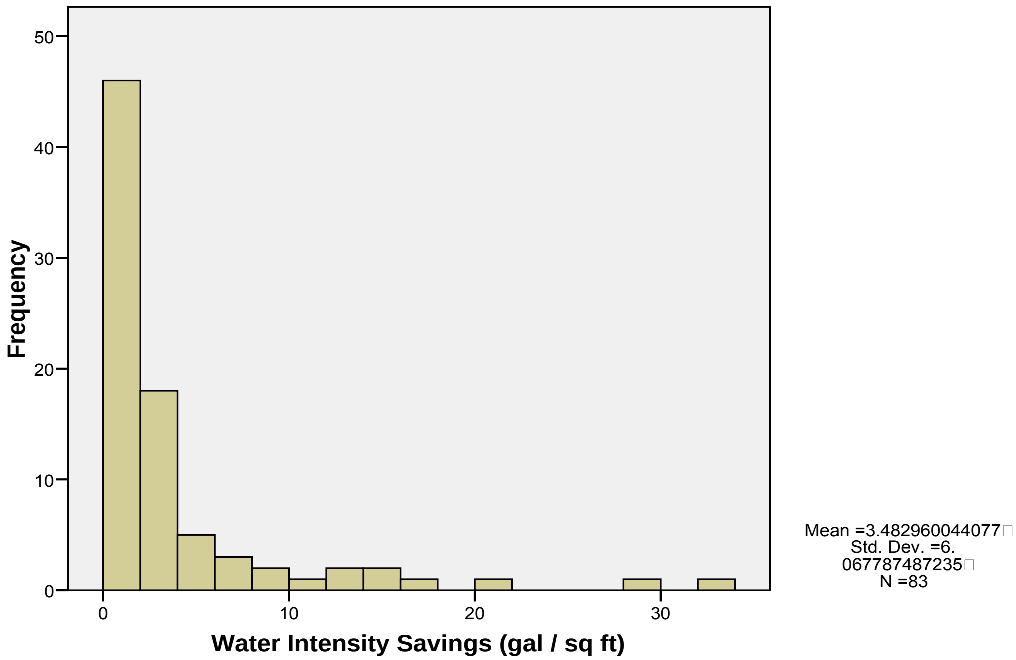
Electricity Intensity Savings (kWh / sq ft)



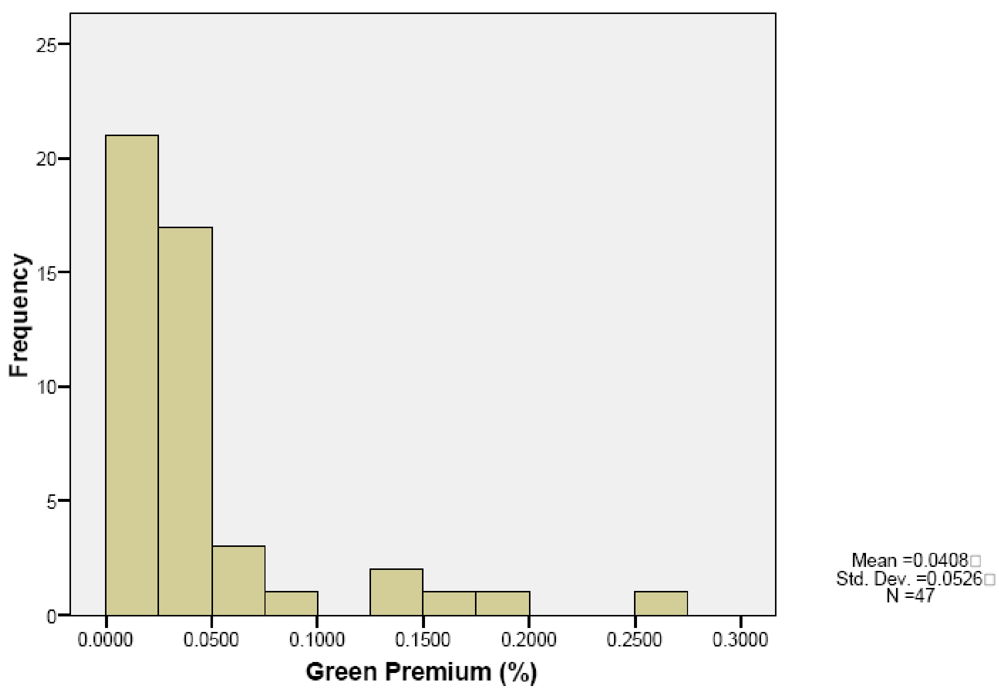
Fuel Intensity Savings (kBtu / sq ft)



Water Intensity Savings (gal / sq ft)



Green Premium (%)



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Vita

Major Nyikos received his commission from the U.S. Air Force Academy in 1995 with a Bachelor of Science degree in engineering sciences. He is a graduate of Euro-NATO joint jet pilot training and the Joint Firepower Control Course. As a member of the 94th Fighter Squadron, Major Nyikos participated in Operation Desert Thunder, Operation Desert Fox, and Operation Southern Watch. While serving as a forward air controller and terminal air control party flight commander, he deployed his flight with the 101st Airborne Division to Kandahar, Afghanistan in support of Operation Enduring Freedom. Major Nyikos was an F-15 instructor pilot and flight examiner, and he was qualified in the joint helmet mounted cueing system and the APG-63/V-2 active electronically scanned array radar. Prior to beginning studies at the Air Force Institute of Technology, he was the Director of Operations of the 2006 Raytheon Trophy winning 12th Fighter Squadron where he participated in and directed air superiority operations in support of Operation Noble Eagle and Operation Northern Denial. Major Nyikos is an intermediate developmental education student at the Air Force Institute of Technology completing a Master of Science degree program in engineering management with a focus in strategic information management. Upon graduation, he will be assigned to the Joint Forces Command J7 staff in Suffolk, Virginia.

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14. ABSTRACT

The 2007 Air Force Sustainable Development and Design Policy mandates the use of Leadership in Energy and Environmental Design (LEED®) criteria for military construction projects. Additionally, the policy authorizes adding two percent of the original building budget to the total building budget in order to fund the resulting sustainable design costs. To determine if the specific sustainable design goals of this policy had statistical support in the population of LEED® certified buildings, the author gathered construction, cost, and utility data on a sample of 160 LEED® certified buildings. Simple correlation and descriptive statistics were used to analyze the resulting database. The correlation analysis suggests that this sample offers no statistically significant correlations between design variables. Furthermore, the descriptive statistics suggest that, although the Air Force policy will certainly achieve some of its goals, the two percent budget increase is likely to be too little to achieve LEED® certification a majority of the time. Without additional design requirements, the analysis also suggests that the policy will not result in buildings that always achieve the utility reduction requirements of the Energy Policy Act of 2005 and Executive Order 13423.

15. SUBJECT TERMS

Green design, sustainable design, cost, benefits, Leadership in Energy and Environmental Design, LEED

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